(12) UK Patent Application (19) GB (11) 2 173 886 A

(43) Application published 22 Oct 1986

(21) Application No 8606383

(22) Date of filing 14 Mar 1986

(30) Priority data
(31) 60/051030 (32) 14 Mar 1985 (33) JP

(51) INT CL⁴
F25D 3/00 F24H 7/00

(52) Domestic classification (Edition H):
F4H G9
F4U 70

(56) Documents cited
None

(58) Field of search
F4H
F4U
Selected US specifications from IPC sub-classes F25D F24H

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(54) Thermal energy storage and discharge system

(57) A thermal energy storage and discharge system comprises a conduit array (9, 17, 21) and pumps (10,18) such that heat transfer medium flows between a heat exchanger (3) arranged to receive thermal energy into said system and a thermal energy storage tank (8) and between said tank and a heat exchanger (7) arranged to discharge thermal energy from said system. Said tank (8) is charged with spheroidal thermal energy storing members (37 Fig. 2,3,4) each charged with a thermal energy storing medium. A bypass conduit (21) branches out from the conduit 17 at a junction (19) upstream of said heat exchanger (7) and rejoining said conduit 17 at a junction (20) downstream of said heat exchanger (7).

Said system further comprises a temperature sensing means (23, 24) arranged to monitor the temperature of said heat transfer medium passing from said junction (19) to said heat exchanger (7) and to generate a signal, a control valve (22) arranged to adjust the flow rate of said heat transfer medium through said conduit (17) and said bypass conduit (21) and a control (25, 26) arranged to operate said control valve (22) in response to said signal to increase or decrease the flow rate of said heat transfer medium through said bypass conduit (17) and said tank (8) when the temperature (t) of said medium monitored by said sensing means (23, 24) deviates from a preset value (T) whereby to reduce the deviation (Δt) from said preset value.

FIG.1

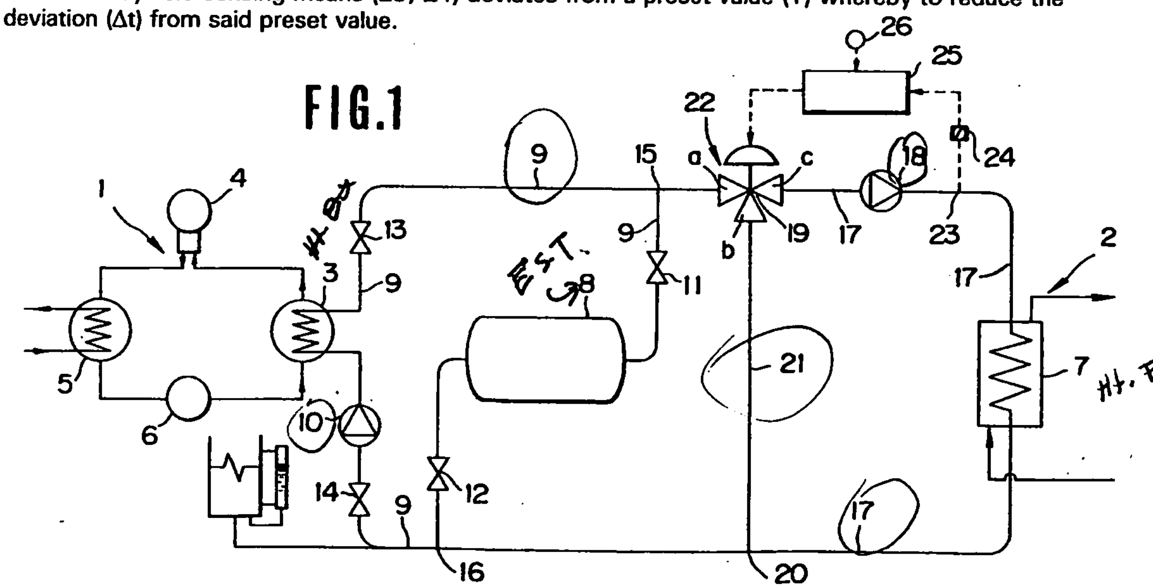

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FIG.1

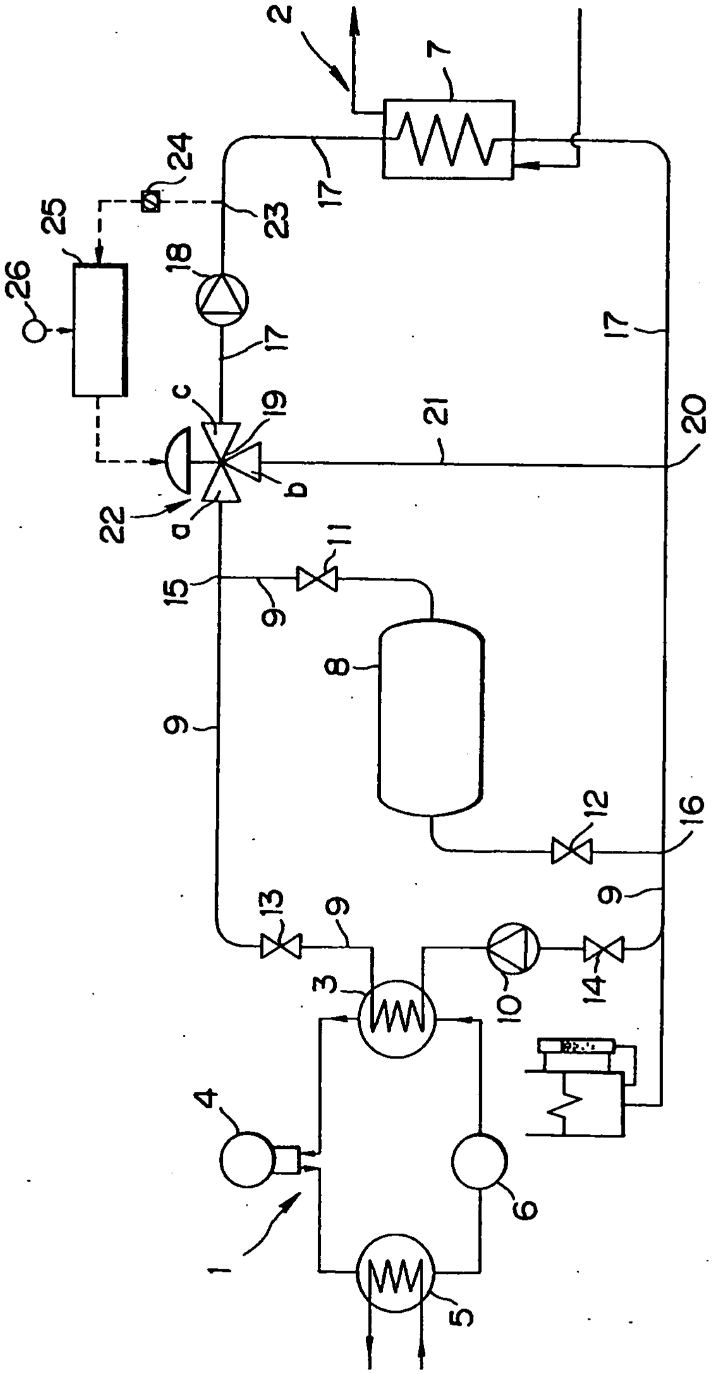

FIG.3

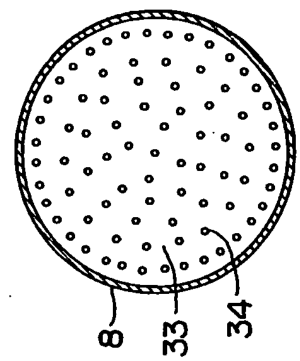
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FIG.2

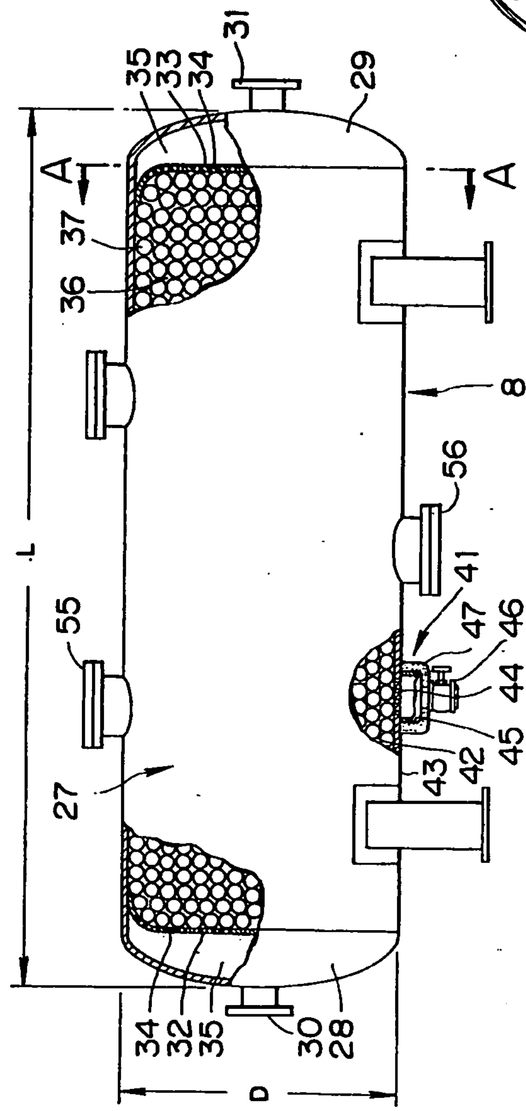
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FIG.4

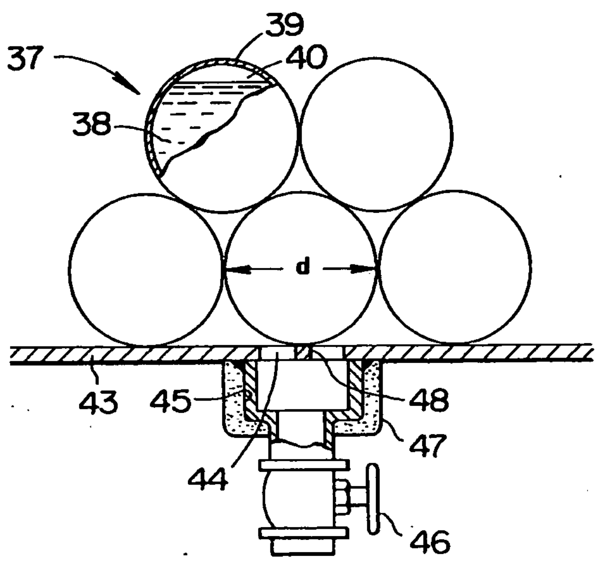

FIG.5

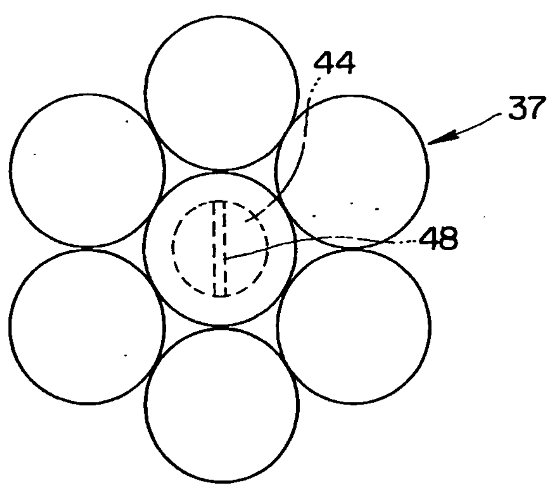

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FIG.6

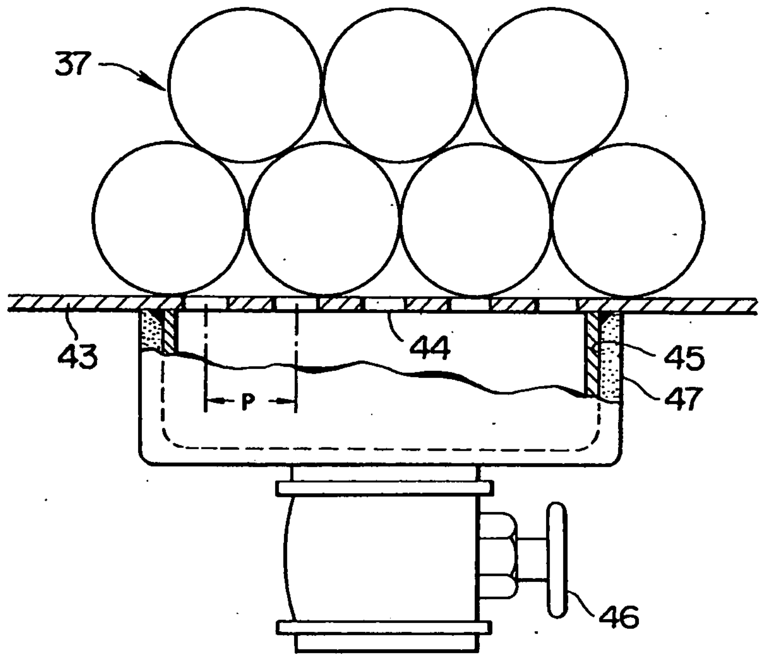


FIG.7

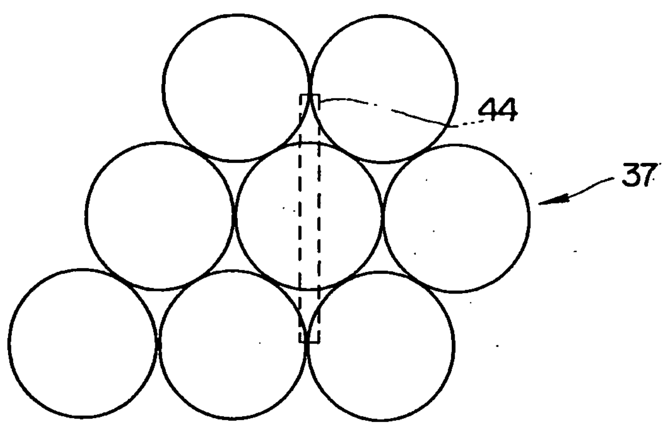


FIG.8

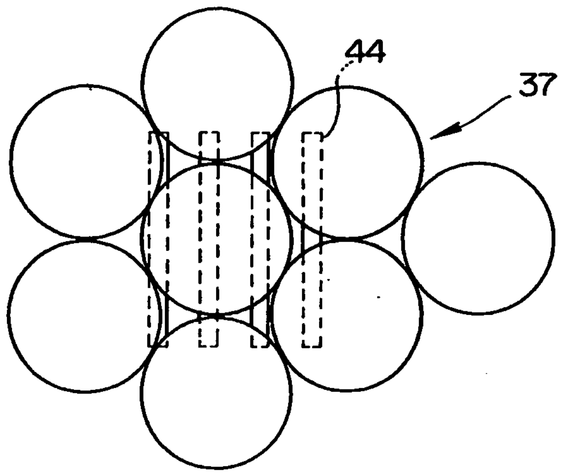


FIG.15

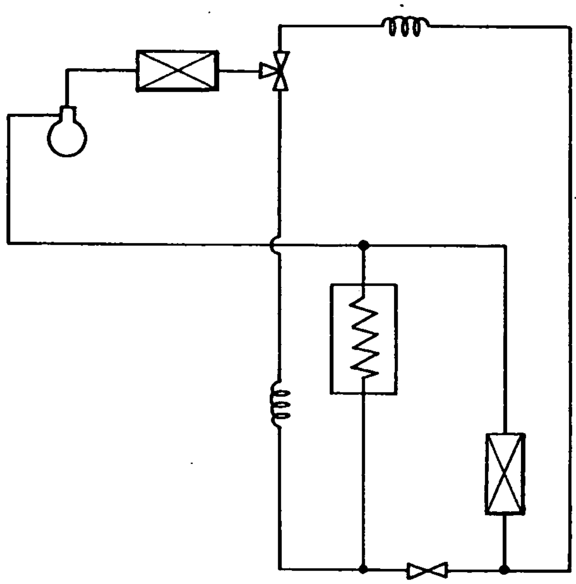


FIG.9

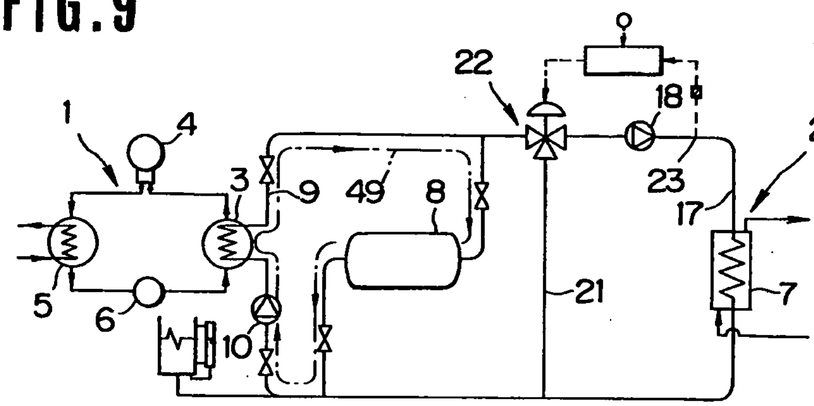


FIG.10

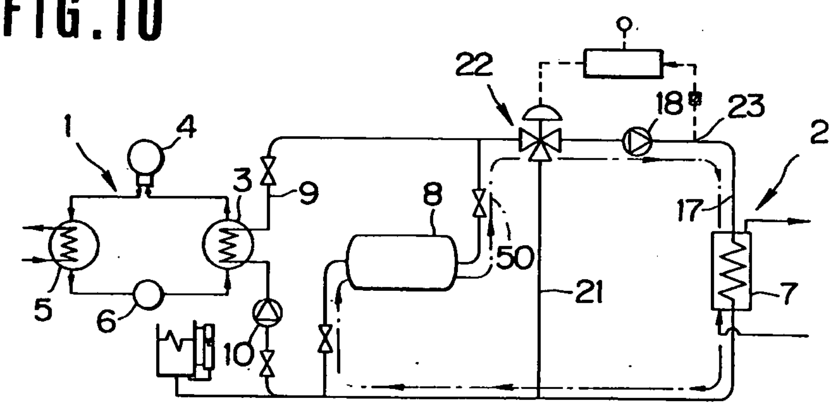


FIG.11

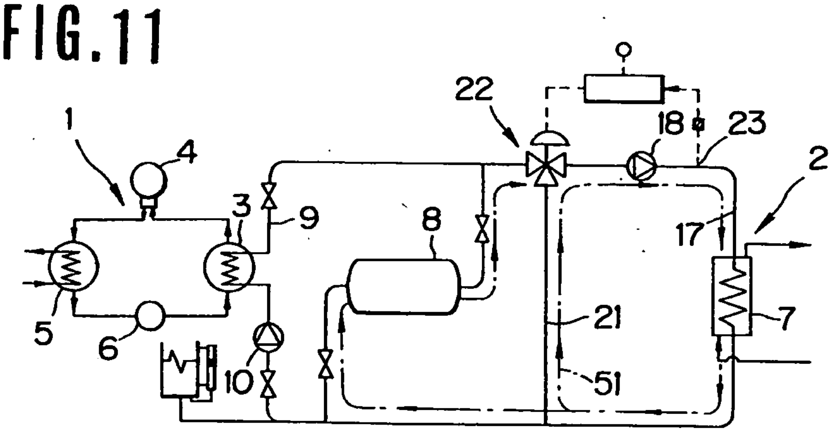


FIG.12

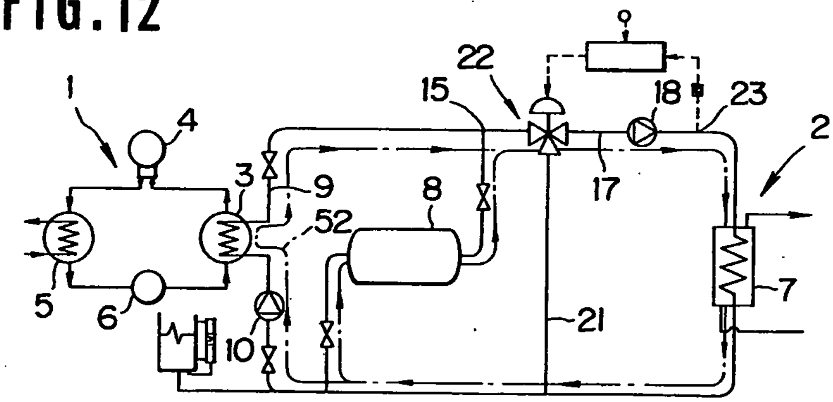


FIG.13

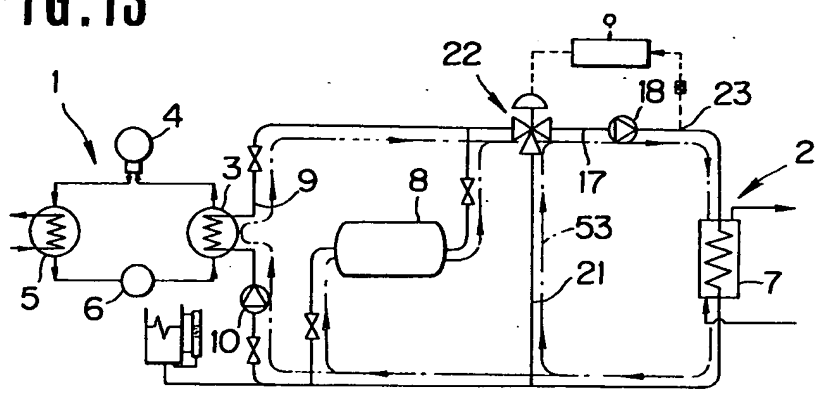
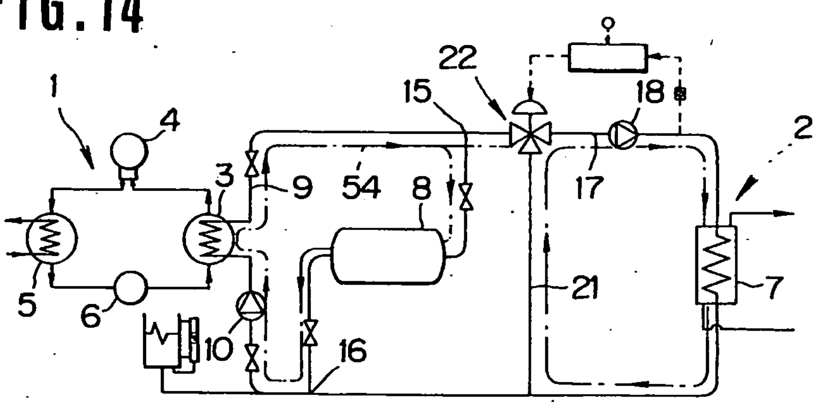


FIG.14



SPECIFICATION

Thermal energy storage and discharge system

The present invention relates to a thermal energy storage and discharge system, more particularly it relates to such a system utilizing latent heat, e.g. based upon the phase change phenomenon in which a substance is melted or solidified at a certain temperature.

As is well known, a thermal energy storing method utilizing a thermal energy storing material which stores thermal energy as latent heat has been recently noted because thermal energy storage density is higher in comparison with a technology utilizing sensible heat so that a considerable quantity of heat can be obtained and because a plant therefor can be compactly constructed. Accordingly, thermal energy storing materials and thermal energy storing tanks utilizing the materials as well as processes, plants, systems or the like utilizing them have been developed and in particular it has been proposed that the thermal energy storing materials be mainly applied to utilization of hot heat obtained from solar energy and the like. Where a system stores thermal energy in a thermal energy storing material in the higher temperature phase, i.e. that stable at temperatures above the phase transition temperature, the system will be referred to hereinafter as storing "hot heat" and where the thermal energy is stored in the thermal energy storing material in the lower temperature phase, the system will be referred to hereinafter as storing "cold heat". In general hot heat storage and discharge systems may be used for heating purposes and cold heat storage and discharge systems may be used for refrigerating purposes.

As one of the proposals, a whole system of a thermal energy storing plant utilizing latent heat can be referred to, for example, in "Energy & Resources", Vol.4, No.4 (1983) published by Energy & Resources Society. In particular, a solar system and an air conditioning system are reported as an experimental application of thermal storage utilizing latent heat in "Energy & Resources", pages 51 to 54. In these known systems, is used a cooling plant, as shown in Fig. 15 hereto, which can operate both in a thermal medium energy storing made therein a heat transfer is discharged from a compressor and is circularly returned back through a condenser and a thermal energy storing tank and in a thermal energy radiating mode wheren the heat transfer medium is circulated between the thermal energy storing tank and an air cooler. This system is more or less satisfactory. However, in the prior art system, during the thermal energy radiating mode, all of the heat transfer medium discharged from the air cooler is merely returned back thereto through the thermal energy storing tank. In other words, the supply of the heat transfer medium to the air cooler (equipment provided at an energy consumption side) and the temperature of the heat transfer medium are not controlled and regulated in response to heat consumption requirements which are defined by the energy consuming equipment. Accordingly, the prior systems still remain in the experimental stage and it is necessary to solve many problems in order to put the systems to practical use.

Thus viewed from one aspect the present invention provides a thermal energy storage and discharge system utilizing latent heat and comprising a conduit array arranged to pass heat transfer medium between a first heat exchanger arranged to receive thermal energy into said system and a thermal energy storage tank arranged to store thermal enegy received into said system and between said tank and a second heat exchanger arranged to discharge thermal energy from said system,

said tank being charged with spheroidal thermal energy storing members each charged with a thermal energy storing medium, said conduit array comprising a first conduit element arranged to pass heat transfer medium under the action of pump means from said first heat exchanger to said tank and to return heat transfer medium from said tank to said first heat exchanger, a second conduit element arranged to pass heat transfer medium under the action of pump means from said second heat exchanger to said tank and to return heat transfer medium from said tank to said second heat exchanger, and a bypass conduit element branching out from said second conduit element at a first junction upstream of said second heat exchanger and rejoining said second conduit element at a second junction downstream of said second heat exchanger, said system further comprising a temperature sensing means arranged to monitor the temperature of said heat transfer medium passing from said first junction to said second heat exchanger and to generate a signal, control valve means arranged to adjust the flow rate of said heat transfer medium through said second conduit element and said bypass conduit element and control means arranged to operate said control valve means in response to said signal to increase or decrease the flow rate of said heat transfer medium through said bypass conduit element and said tank when the temperature of said medium monitored by said sensing means deviates from a preset value whereby to reduce the deviation from said preset value.

Viewed from an alternative aspect however, the invention provides a thermal energy storage system utilizing latent heat comprising a heat transmitting tube for a time of thermal energy storing mode and a heat transmitting tube for a time of thermal energy radiating mode, said heat

transmitting tube for the thermal energy storing mode being arranged to pass a heat transfer medium, which is discharged from a heat exchanger provided at an energy generation side, to a thermal energy storing tank under the action of a pump and return said heat transfer medium to the heat exchanger provided at said energy generation side, said thermal energy storing tank densely receiving small spherical thermal energy storing members therewithin, each of said small spherical thermal energy storing members being charged with a thermal energy storing medium, said heat transmitting tube for the thermal energy radiating mode being branched out from a part of the first-mentioned heat transmitting tube at the upstream side of said thermal energy storing tank and connected, through a heat exchanger provided at an energy consumption side, to a part of the first-mentioned heat transmitting tube at the downstream side of said thermal energy storing tank, thereby passing a heat transfer medium, which has been discharged from the heat exchanger provided at said energy consumption side, to the thermal energy storing tank under the action of a pump and then passing said heat transfer medium to the heat exchanger provided at said energy consumption side, wherein said thermal energy storing system utilizing latent heat further comprises a bypass tube for connecting the parts of the heat transmitting tube for the thermal energy radiating mode at the upstream and downstream sides of the heat exchanger provided at said energy consumption side and a three-way control valve arranged at the junction point between the heat transmitting tube for the thermal energy storing mode and the bypass tube which are so constructed that when the temperature t of the heat transfer medium detected at a position short of the point where the heat transfer medium enters through said junction point into the heat exchanger provided at said energy consumption side becomes higher than a predetermined temperature T at the same position, the difference Δt between the temperatures is used as a control signal to actuate said three-way control valve to cause a part of the heat transfer medium, which is discharged from the heat exchanger provided at said energy consumption side, to pass through the bypass tube and return into the heat exchanger provided at said energy consumption side, thereby adjusting the flow rate of the heat transfer medium which is passed through said thermal energy storing tank.

Thus the present invention provides a thermal energy storing system utilizing latent heat which is carried out on the basis of the fact that a quantity of thermal energy radiated from a thermal energy storing tank to a heat transfer medium can be varied in response to a change of a flow rate of the heat transfer medium passed through the thermal energy storing tank, wherein, in a thermal energy radiating or discharge mode, a real temperature of the heat transfer medium is detected as a control signal when it enters into a heat exchanger provided at the energy consumption or discharge side of the system, wherein the flow rate of the heat transfer medium passed through the thermal energy storing tank is regulated in response to a control signal so that a temperature of the heat transfer medium supplied to the heat exchanger of the energy consumption side is, at all times, in accordance with energy consumption requirements of the energy consumption side, and wherein the control of operation can be easily carried out.

The thermal energy storing tank is very important because efficient operation of the thermal energy storing systems or plants therefor depends upon an arrangement of the thermal energy storing tank which forms a part of the systems or plants. In most of the prior systems or plants, a shell and tube type or a spiral coil type is used as a thermal energy storing tank and comprises a tank body, a tube member extending through the tank body, and a phase changing substance or thermal energy storing medium with which the tank body is filled. The thermal energy storing tank as shown in Fig. 15 hereto and a thermal energy storing tank as disclosed in Japanese Patent Laid-Open No. 53–9596 are of these types. On the other hand, another type is proposed as disclosed in Japanese Patent Laid-Open No. 53–25939. This thermal energy storing tank comprises a cylindrical steel vessel filled with the thermal energy storing medium, said vessel being supported on rollers and being rotated by a small drive motor so that heat is exchanged between the thermal energy storing medium and a gas. It may be noted that according to recent researches of the present inventors, it has been found that the thermal energy storing tank has a constructional limitation in increasing the volume (thermal energy storage capacity) of the thermal energy storing medium within the tank, that there are difficulties in shortening the thermal energy storage/thermal energy radiation time, that there is a limitation in shaping the thermal energy storing vessel using a circular tube and a spiral coil so that they cannot be immediately incorporated in the existing thermal energy storing tanks, that the durability of the thermal energy storing tank is poor because cracks may be caused in corners of the tubes, etc. Accordingly, in order to promote the thermal energy storing system utilizing latent heat from the experimental stage to the practical stage, it has been necessary to develop a novel thermal energy storing tank by which the prior tank can be replaced.

In order to respond to the demand mentioned above, some experiments and researches have been tried by the present inventors so that it is found that the above-mentioned problems can be solved by use of small spherical thermal energy storing members which are filled with the phase changing substance or the thermal energy storing medium. Japanese Patent Application No. 59–52974 discloses a thermal energy storing tank which receives the small spherical

thermal energy storing members. As the systems according to the present invention include a said thermal energy storing tank having such spherical members, the above-mentioned problems of the prior art can be also solved by the present invention. However, the invention disclosed in Japanese Patent Application No. 59–52974 involves some unsolved problems as follows:

One of the unsolved problems is to develop means for improving a contact relationship between the small spherical thermal energy storing members and the heat transfer medium passing through the thermal energy storing tank becuase it is necessary to uniformly contact the heat transfer medium with the small spherical members in each of sections thereof in order to obtain a stable operation. There may be two ways for developing said improving means: one is to diffuse and spread out the heat transfer medium as much as possible when it is introduced from the inlet port of the tank onto the small spherical members received therewithin; and the other way is to avoid causing locally non-uniform convection in the heat transfer medium within the tank because if non-uniform convection is locally caused, the heat conductivity is non-uniform in each of the sections of the heat transfer medium so that uniform heat exchange with the small spherical members cannot be achieved.

Another unsolved problem was to develop means for determining an optimum pressure loss which governs a velocity of the heat transfer medium (which is considerably affected by the friction) at the time when it is passed through the thermal energy storing tank because it is necessary to determine an optimum residence time of the heat transfer medium within the tank for the reason that as the residence time of the heat transfer medium increases, the thermal efficiency of the heat exchange increases. Accordingly, it is desirable to determine an optimum diameter and an optimum length of the thermal energy storing tank. In addition, as one of the unsolved problems, the drainage of the tank which is very important for practical purposes should be noted because it has to be carried out after the tank receives the small spherical thermal energy storing members.

Accordingly, we have now found that the thermal energy storage tank advantageously comprises a hollow closed ended cylindrical body member having a substantially horizontal cylindrical axis, having inlet and outlet ports for heat transfer medium passing through the system at the opposite ends of the body member, and having flow diffusing members, e.g. multiply perforated circular plate members, within the body member and in facing relation with the ports. The cylindrical body member advantageously has a diameter to length ratio of from 1:3 to 1:6 and preferably has on its underside at least one drainage port to permit the drainage from said body member of heat transfer medium contained therein, the openings to said drainage port being so dimensioned as to prevent said spheroidal thermal energy storing members from being drawn out therethrough.

Viewed from a still further aspect the invention therefore provides a thermal energy storage system utilizing latent heat comprising a heat transmitting tube for a time of thermal energy storing mode and a heat transmitting tube for a time of thermal energy radiating mode, said heat transmitting tube for the thermal energy storing mode being arranged to pass a heat transfer medium, which is discharged from a heat exchanger provided at an energy generation side, to a thermal energy storing tank under the action of a pump and return said heat transfer medium to the heat exchanger provided at said energy generation side, said thermal energy storing tank densely receiving small spherical thermal energy storing members therewithin, each of said small spherical thermal energy storing members being charged with a thermal energy storing medium, said heat transmitting tube for the thermal energy radiating mode being branched out from a part of the first-mentioned heat transmitting tube at the upstream side of said thermal energy storing tank and connected, through a heat exchanger provided at an energy consumption side, to a part of the first-mentioned heat transmitting tube at the downstream side of said thermal energy storing tank, thereby passing a heat transfer medium, which has been discharged from the heat exchanger provided at said energy consumption side, to the thermal energy storing tank under the action of a pump and then passing said heat transfer medium to the heat exchanger provided at said energy consumption side, wherein said thermal energy storing system utilizing latent heat further comprises a bypass tube for connecting the parts of the heat transmitting tube for the thermal energy radiating mode at the upstream and downstream sides of the heat exchanger provided at said energy consumption side and a three-way control valve arranged at the junction point between the heat transmitting tube for the thermal energy storing mode and the bypass tube which are so constructed that when the temperature t of the heat transfer medium detected at a position short of the point where the heat transfer medium enters through said junction point into the heat exchanger provided at said energy consumption side becomes higher than a predetermined temperature T, at the same position, the difference Δt between the temperatures is used as a control signal to actuate said three-way control valve to cause a part of the heat transfer medium, which is discharged from the heat exchanger provided at said energy consumption side, to pass through the bypass tube and return into the heat exchanger provided at said energy consumption side, thereby adjusting the flow rate of the heat transfer medium which is passed through said thermal energy storing tank, wherein the thermal energy

storing tank is of a horizontal stationary type, which comprises a cylindrical body, end caps fixed to the opposite ends of said cylindrical body, connection ports, flow diffusing members disposed near the opposite ends of the cylindrical body in confronting relation to said connection ports, and a draining means formed at the lower position of the horizontal body, wherein the ratio of the diameter *D* to the horizontal length *L* of the tank is within the range 1:3–6 and wherein the tank contains a plurality of small spherical thermal energy storing members, each filled with a thermal energy storing medium, which are closely received in an inside chamber of the tank defined by said flow diffusing members, said draining means being formed of a draining tube, one or more draining openings and a valve for closing said draining tube, said one or more draining openings being so formed as to inhibit the passage of said small spherical thermal energy storing members but to allow the passage of the heat transfer medium.

Thus the invention provides a thermal energy storing system utilizing latent heat which is designed so that a thermal energy storing tank having a given volume can be given a maximum thermal energy storage capacity and that the thermal conductivity per unit volume is so high as to be capable of shortening the thermal energy storage/radiation time as much as possible, wherein portions of the tank which may be subjected to corrosion are few so that the durability thereof can be increased, and wherein the design of the tank need not be limited by thermal energy storing members. Thus, also the present invention provides a thermal energy storing system utilizing latent heat, wherein there is provided means for uniformly diffusing and spreading out a heat transfer medium within a thermal energy storing tank in a plane perpendicular to a direction along which it enters into the tank, especially just after the entrance, so that the heat transfer medium is uniformly contacted with small spherical thermal energy storing members. Furthermore, the present invention provides a thermal energy storing system utilizing latent heat, wherein a thermal energy storing tank per se may be of a horizontal stationary type so as to eleiminate or reduce effects resulting from external forces and the force of gravity, by which unforeseen convection is caused in a heat transfer medium, whereby a uniform convection is caused in each of sections of a mass of small spherical thermal energy storing members so that a uniform heat conduction can be obtained in each of said sections. Moreover, the present invention provides a thermal energy storing system utilizing latent heat, wherein there is provided a thermal energy storing tank which assures a velocity of a heat transfer medium (residence time thereof within the tank) for obtaining a good thermal efficiency in a heat exchange by determining an optimum relationship between the diameter and the length of the tank, which governs a pressure loss of the heat transfer medium passing through the tank. According to some experiments of the present inventors, it has been found that the optimum relationship is the ratio of the diameter to the length, which can be determined within the range 1:3–6.

The present invention also provides a thermal energy storing system utilizing latent heat, wherein there is provided a thermal energy storing tank which is designed so that a drainage of the tank in which small spherical thermal energy storing members are densely received and settled can be easily carried out, if necessary, without falling the small spherical members downwardly, and that is convenient to handle in situ.

In the thermal energy storing system utilizing latent heat as mentioned above, one of the most basic elements is a thermal energy storing medium which is charged in thermal energy storing members received in a thermal energy storing tank. Many researches and developments of such a heat transfer medium have been promoted so that many substances for using as the thermal energy storing medium are reported. However, most of the reported substances have a melting point or solidification point which is above 5°C. A few substances having a melting point or solidification point which is below 0°C are merely proposed by Japanese Patent Laid-Open No. 59–93780 and others. However, they are directed to the thermal energy storing medium per se and thus disclose few systems or plants utilizing it.

We have now found that by charging the thermal energy storing members with an aqueous eutectic mixture, e.g. containing Na_2CO_3, $KHCO_3$, $BaCl_2$, KCl, NH_4Cl, NH_4NO_3, $CaCl_2$, $NaBr$, $MgCl_2$, K_2CO_3, $NaOH$ or H_2SO_4, energy storage and discharge systems according to the invention may advantageously be arranged to store and discharge cold heat.

Where a thermal energy storing medium having a melting/solidification point which is −3, −6, −8 or −10°C is charged in the small spherical thermal energy storing members, the system is suitable for a cold heat soruce which is used in a storage and/or a reaction process involved in beer production factories, beverage production factories or the like. Also, the system is suitable for a cold heat source which is used in a low temperature reactor included in a dairy plant. Furthermore, the system is suitable for a cold heat source which is used in a freezer involved in a display case for goods, products or the like. In addition, the system is suitable for a cold heat source which is used in a storage involved in a distribution industry of frozen foods, fruits, flowers or the like.

Where a thermal energy storing medium having a melting/solidification point which is −15, −17, −18 or −21°C is charged in the small spherical thermal energy storing members, and wherein the charged small spherical members are received in the thermal energy storing tank the

system is suitable for a cold heat source which is used in a meat storage involved in a slaughterhouse, a meat distribution center or the like. Also, the system is suitable for a cold heat source which is used in a rink for ice skating. Furthermore, the system is suitable for a cold heat source which is used in a storage of medicine or blood involved in medicine industry.

Where a thermal energy storing medium having a melting / solidification point of 0°C is charged in the small spherical thermal energy storing members, and wherein the charged small spherical members are received in the thermal enegy storing tank the system is suitable for a cold heat source which is used in a cooler of buildings.

Where a thermal energy storing medium having a melting/solidification point which is −28, −33 or −37°C is charged in the small spherical thermal energy storing members, and wherein the charged small spherical members are received in the thermal energy storing tank, the system is suitable for a cold source which is used in a freezing warehouse.

Where a thermal energy storing medium having a melting / solidification point which is 64°C is used the system is suitable for a heating of buildings, a hot-water supply, a hot-well or the like.

Furthermore, in the systems of the present invention although the thermal energy storing medium is subjected to many times of repetition of melting and solidification, the systems can nonetheless be stably operated.

In the systems of the invention, thermal energy storing and thermal energy radiating operations may be carried out as follows:

1) In the thermal energy storing operation, the thermal energy generator is driven and the three-way control valve is so changed that the heat transfer medium is circulated between the (first) heat exchanger and the thermal energy storing tank. In other words, the heat transfer medium is circulated only along the heat transmitting tube for the thermal energy storing mode (the first conduit element) so that it is passed through the spaces among the small spherical thermal energy storing members held in the thermal energy storing tank. In this process, the thermal energy storing medium is melted or solidified at the melting/solidification point. In particular, when hot heat is the subject of utilization, the latent heat is stored in the melted medium. To the contrary, when cold heat is the subject of utilization, the latent heat is stored in the solidified medium.

2) In the thermal energy radiating operation, the energy generator is stopped and the three-way control valve is so changed that the heat transfer medium is circulated by the pump between the thermal energy storing tank and the (second) heat exchanger provided at the energy consumption side. Therefore, the heat transfer medium is passed through the spaces among the small spherical thermal energy storing members received in the thermal energy storing tank. In this process, heat is transmitted from the small spherical thermal energy storing members to the heat transfer medium. In particular, if hot heat is the subject of utilization, the latent heat is absorbed by the heat transfer medium on the solidification of the thermal energy storing medium. On the other hand, if cold heat is the subject of utilization, the latent heat is absorbed from the heat transfer medium on the melting of the thermal energy storing medium. In this way, the heat exchange is carried out so as to bear a load of the energy to the energy consumption side.

Now, in the case where t is an actually detected temperature of the heat transfer medium passed through a position on the upstream side of the (second) heat exchanger provided at the energy consumption side, T is a setting temperature which is set at the same position for controlling, and Δt is a difference between the real temperature t and the setting temperature T, if t is equal to T, the heat transfer medium is circulated only between the heat transmitting tube for the thermal energy storing mode and the heat exchanger provided at the energy consumption side so that a first thermal energy radiating mode is obtained. By the way, if it is said that t is over or higher than T, this can be interpreted in two ways. That is, if cold heat is the subject of utilization, it means $t<T$ so that the real temperature of the heat transfer medium is over the setting temperature T at the inlet port of the heat exchanger provided at the energy consumption side thereby causing a too cold condition, whereas if hot heat is the subject of utilization, it means $t>T$ so that the real temperature of the heat transfer medium is over the setting temperature at the inlet port of the heat exchanger provided at the energy consumption side thereby causing a too hot condition. In short, when t is over T, the three-way control valve is changed by using the diffemce Δt as a control signal so that a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the bypass tube and is then returned back to said heat exchanger so that a second thermal energy radiating mode is obtained.

In this way, the flow rate of heat transfer medium which is passed through the thermal energy storing tank is reduced and then the quantity of radiation energy is also decreased, whereby the temperature of the heat transfer medium passed through the position where is on the upstream side of the inlet port of the heat exchanger provided at the energy consumption side is controlled and regulated by using the setting temperature as a reference.

On the other hand, in the case where the quantity of radiation energy received from the

thermal energy storing tank is decreased so that the relationship between the real temperature t and the setting temperature T is changed into $t > T$ (when the cold heat is the subject of utilization) or $t < T$ (when the cold heat is the subject of utilization), a closure of the bypass tube which is performed in this changing process is electrically detected so that the pump and the heat exchanger provided at the energy generation side are, if necessary, drived through a control system which is actuated by the detection. As the result, a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the heat exchanger provided at the energy generation side and is then returned back to the heat exchanger provided at the energy consumption side so that a backup operation mode or a third thermal energy radiating mode is obtained.

In this backup operation mode, if t is over T, the three-way control valve is changed so that a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the bypass tube and is then returned back to said heat exchanger while the flow rate of the heat transfer medium which is controlled and regulated in proportion to the difference Δt, whereby a fourth thermal energy raditating mode is obtained.

In the fourth thermal energy radiating mode, as a flow rate of the heat transfer medium which is passed through the bypass tube is increased, a flow rate of the heat transfer medium which is fed to the primary side of said pump is decreased. When the flow rate of the heat transfer medium fed to the primary side of the pump becomes less than the output capacity thereof, a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy generation side is directed to the primary side of said pump through the thermal energy storing tank and is then returned back to said heat exchanger so that both the thermal energy storing mode and the thermal energy radiating mode are obtained.

In the thermal energy storing and thermal energy radiating modes, since the thermal energy storing tank of the present invention is so constructed as to receive the small spherical thermal energy storing members therein, it is possible to use about 68% of a given volume of the thermal energy storing tank as a volume for an energy storage capacity so that the energy storage capacity can be considerably more increased than thermal energy storing tanks of other types while it is possible to shorten the thermal energy storage/radiation time. Especially, as the heat transfer medium can be spread out within the thermal energy storing tank during the passage thereof, the advantages or merits as mentioned above is sufficiently exhibited. In addition, a trouble about corrosion is hardly caused. Also, since the thermal energy storing tank per se is of a horizontal stationary type, it is unnecessary to use a power source and it is possible to gain a sufficient durability, while convections resulting from external rotational forces and the force of gravity are not caused in the heat transfer medium passing through the thermal energy storing tank. A main convection which may be caused within the tank is a unidirectional stream which moves from one side to the other side so that a generally uniform heat conduction is attained in each of sections of a mass of the small spherical thermal energy storing members, whereby when the thermal energy storing tank is manufactured as a product, a stable thermal energy storage/radiation characteristic is obtained in the products. On the other hand, in the thermal energy storing tank of the horizontal stationary type, since the ratio of the diameter D to the length thereof is determined within the range 1 : 3~6 so that it is possible to determine the optimum pressure loss at the time when the heat transfer medium is passed through the tank, thereby assuring the optimum velocity of the heat transfer medium (residence time within the tank) for obtaining a good thermal efficiency in the heat exchange. Furthermore, the thermal energy storing tank may be provided with the draining tube and the one or more draining openings which prevent the small spherical thermal energy storing members from passing out therethrough but allow the passage of the heat transfer medium therethrough, whereby the drainage of the tank can be easily carried out.

In the thermal energy storing system utilizing latent heat of the second-mentioned type according to the present invention, the small spherical thermal energy storing members received in the thermal energy storing tank are charged with a liquid which is mainly composed of one of the following aqueous solutions:

eutectic mixture of sodium carbonate (Na_2CO_3) aqueous solution;
eutectic mixture of potassium bicarbonate ($KHCO_3$) aqueous solution;
eutectic mixture of barium chloride ($BaCl_2$) aqueous solution;
eutectic mixture of potassium chloride (KCl) aqueous solution
eutectic mixture of ammonium chloride (NH_4Cl) aqueous solution;
eutectic mixture of ammonium nitrate (NH_4No_3) aqueous solution
eutectic mixture of sodium nitrate ($NaNO_3$) aqueous solution;
eutectic mixture of calcium chloride ($CaCl_2$) aqueous solution;
eutectic mixture of sodium bromide ($NaBr$) aqueous solution;
eutectic mixture of magnesium chloride ($MgCl_2$) aqueous solution;
eutectic mixture of potassium carbonate (K_2CO_3) aqueous solution;
eutectic mixture of sodium hydroxide ($NaOH$) aqueous solution; and aqueous solution including

water (H_2O) and small quantities of sulphuric acid (H_2SO_4) added thereto.

By using these solutions, there is provided the thermal energy storing system utilising latent heat which can be operated at the melting/solidification point of −3, −6, −8, −10, −15, −17, −18, −21, −28, −33, −37, 64 or 0°C.

Preferred embodiments of the present invention will now be described by way of example with reference to the accompanying drawings, in which:–

Figure 1 is a schematic block diagram of a thermal energy storing system according to the present invention;

Figure 2 is a partial cutaway view of a thermal energy storing tank suitable for use in a system according to the invention;

Figure 3 is a cross-sectional view taken on line A–A of Fig. 2;

Figure 4 is a partial cutaway side view showing one embodiment of draining means for a thermal energy storing tank in a system according to the invention;

Figure 5 is a view showing the drainage means of Fig. 4 seen from the upper side through small spherical thermal energy storing members;

Figure 6 is a partial cutaway side view showing another embodiment of draining means for a thermal energy storing tank;

Figures 7 and 8 are views showing further embodiments of draining means, viewed from the upper side through small spherical thermal energy storing members;

Figures 9 to 14 are schematic block diagrams corresponding to Fig. 1, illustrating heat transfer medium flow in thermal energy storing and radiating modes; and

Figure 15 is a schematic block diagram showing a prior art system.

In the embodiments illustrated, the present invention is applied to a system in which a cooler and/or a freezer are used as energy consumption equipment, i.e. where cold heat is stored and discharged.

In Fig. 1 which shows a whole of the thermal energy storing system, reference numeral 1 denotes a cold heat generator side and reference numeral 2 denotes a cooler/freezer side in which the cold heat is utilized. The cold heat generator side 1 includes a heat exchanger or a vaporizer 3, a compressor 4, a condenser 5 and expansion valve 6. The cooler/freezer side 2 includes a heat exchanger or a chiller 7.

In order to circulate a heat transfer medium between the vaporizer 3 and a thermal energy storing tank 8 during the thermal energy storing mode, there is provided a heat transmitting tube 9 therebetween. A pump 10 is provided in the heat transmitting tube 9 for the thermal energy storing mode at the upstream side of the vaporizer 3. Opening and closing valves 11 and 12 are provided in the tube 9 at the upstream and downstream sides of the tank 8, respectively. Also, opening and closing valves 14 and 13 are also provided in the tube 9 at the upstream and downstream sides of the vaporizer 3 respectively.

Branching points 15 and 16 are provided in the tube 9 for the thermal energy storing mode at the upstream and downstream sides of the thermal energy storing tank 8, respecitvely. A heat transmitting tube 17 for the thermal energy radiating mode extends from the branching point 15 to the branching point 16 through the chiller 7. A pump 18 is provided in the heat transmitting tube 17 at the upstream of the chiller 7. A branching point 19 is provided in the tube 17 for the thermal energy radiating mode at the upstream side of the chiller 7 and between it and the branching point 15, and a branching point 20 is provided in the tube 17 at the downstream side of the chiller. A bypass tube 21 extends between the branching points 19 and 20. A three-way control valve 22 is disposed at the branching point 19. A three-way changing action of the three-way control valve 22 is carried out under a proportional control on the basis of a control signal which derives from a temperature detected from the heat transfer medium passing through a detection position 23 where is on the upstream side of the chiller 7 or between the chiller 7 and the pump 18. In Fig. 1, reference numeral 24 denotes a thermal sensor, reference numeral 25 a control device and reference numeral 26 a setting device.

The changing action requirements of the three-way control valve 22 are defined as follows:

O1 During the thermal energy storing operation

Inlet port *a*: close, Inlet port *b*: open, Outlet port *c*: open

C©C2During the thermal energy radiating operation

O21: During the first thermal energy radiating mode in which the relationship between t and T is $t=T$ and after the backup operation in which the relationship is changed into $t>T$.

Inlet port *a*: open, Inlet port *b*: close, Outlet port *c*: open

01C2–2: During the thermal energy radiating mode in which the relationship is changed into $t<T$.

Inlet port *a*: open, Inlet port *b*: open, Outlet port *c*: open

Wherein:

t=a temperature which is actually detected from the heat transfer medium passing through the detection position 23 where is on the upstream side of the chiller 7;

T=a setting temperature which is set for controlling a temperature of the heat transfer medium passing through the detection position 23 where is on the upstream of the chiller

7; and

Δt=a difference between the temperaures *t* and *T*, an opening degree of inlet ports *a* and *b* is proportionally controlled in response to Δt.

The control system is so designed that the pump 10 provided in the tube 9 for the thermal energy storing mode is manually or automatically actuated only during the thermal energy storing mode. The pump 18 provided in the tube 17 for the thermal energy radiating mode is manually or automatically actuated only during the thermal energy radiating mode.

The thermal energy storing tank 8 which is a part of this system will be more particularly explained below:

The tank 8 is of a horizontal stationary type and comprises a cylindrical body 27 and end caps 28 and 29 secured to right and left ends of the cylindrical body 27, respectively.

Connecting ports 30 and 31 are formed at the centers of the end caps 28 and 29 and the thermal energy storing tank 8 is connected to the heat transmitting tube 9 through the connecting ports 30 and 31. Diffusing members 32 and 33 are disposed like as a partition wall within the cylindrical body 27 in the vicinity of the right and left ends of the cylindrical body 27 so that they are opposed to the connecting ports 30 and 31, respectively. A plurality of flowing perforations 34 are formed in the diffusig members 32 and 33. That is, the plurality of flowing perforations 34 serves to communicate the interior 36 of the tank 8 with a chamber 35 which is partitioned off by the diffusing member 32. Preferably, the formation of the peforations 34 is achieved in such a manner that a number of the perforations is gradually increased from the center of the diffusing members 32 and 33 toward the periphery thereof so that they have a substantially equal number of the perforations per unit area anywhere. A large number of small spherical thermal energy storing members 37 is densely received in the interior 36 of the tank 8. The small spherical thermal energy storing members are formed of a shell 39 which is charged with a thermal energy storing medium 38. When the thermal energy storing medium changes its phase from the liquid phase into the solid phase at the solidification point, it stores the cold heat as a latent heat of the solidification. Then, when the thermal energy storing medium changes it phase from the solid phase into the liquid phase, it radiates the latent heat as a cold heat.

Each of the small spherical members 37 has a diameter which may conveniently be within the range from 20mm to 200mm. For example, the diameter may be about 65mm. However, a total quantity of thermal energy storage/radiation is determined by requirements of the cooler and/or the freezer, requirements of the thermal energy storing and radiating operations and the like. Accordingly, the diameter should be selected so that sufficient heat transmitting area can be obtained from the small spherical members to satisfy the demanded quantity of thermal energy storage/radiation. On the other hand, the larger the number of the small spherical members 37 received in the tank 8 having a given volume is (that is, the smaller a diameter of the small spherical members 27), the higher the cost for producing the small spherical members is. Therefore, when the small spherical thermal energy storing members are produced, it is preferable to take the production requirements into account in addition to the requirements as mentioned above.

As a material for forming the spherical shell 39, there are various materials such as metals, synthetic resins and the like. However, the material of the shell 39 should be selected in due consideration of: durability by which the shell can maintain its spherical shape against an external foce and an internal force; thermal resistance; workability; et cetera. In the present invention, a size of the shell 39 is decided so that when the thermal energy storing medium 38 has the liquid phase, a space 40 which is occupied by the thermal energy storing medium 38 is formed within the shell 39. At the same time, a size of the space 40 is determined so that an expanded volume of the thermal energy storing medium during the solidification can be absorbed by the space 40 and an expansion of the shell 39 per se. The expansion of the shell 39 is caused by the expansion pressure resulting from the solidification of the thermal energy storing medium 38. When the thermal enery storing medium 38 changes its phase from the solid phase into the liquid phase, the shell 39 is subjected to contraction, but there remains the predetermined volume of the space 40 within the shell 39. For example, if the thermal energy storing medium 38 is solidified so that its volume is increased by 1.08 times in comparison with the liquid volume (8% increment), the size of the space 40 may be determined so that it absorbs the 5.5% part of the 8% increment, the remaining (the 2.5% part) being absorbed by the expansion of the shell 39. In other words, when the spherical shell 39 which is made by using a blow molding process or a vacuum forming process is charged with the thermal energy storing medium (of course, liquid phase) by means of an injection or the like, there remains a space having a volume corresponding to the 5.5% part, that is, the space 40 is formed within the shell 39.

The spherical shell 39 per se is hard, but it is thin. Therefore, the shell 39 is expansible so that it can be expanded by the internal pressure which is caused at the time when the thermal energy storing medium is solidified. Also, when the thermal energy storing medium changes its

phase from the solid phase into the liquid phase, it is returned back to the original condition, there remaining the predetermined space within the shell. As a material for forming the spherical shell 39, it is possible to select from the various materials such as metals, synthetic resins or the like. However, in order that the shell 39 can be easily expanded, a material which is rich in expansibility and contactibility should be selected. In addition to these characteristics, when other characteristics such as durability, thermal resistance and workability are taken into consideration, polypropylene and high-density polyethylene, especially among various materials, are suitable for the spherical shell 39. On the other hand, with respect to the expansion of the shell 39, matters on a design of the shell should be also taken into consideration. Since the shell is expanded by the internal pressure which is caused by the cubical expansion resulting from the solidification of the thermal energy storing medium 38, it is necessary to adjust a degree of expansion on the shell so that it cannot be broken. To this end, a size of the space 40 is determined in due consideration of a quantity of the cubical expansion of the thermal energy storing medium used. In this case, it is necessary to carry out the expansion and the contraction of the shell within an elastic limit which is determined by a material, a radius and a thickness of the shell. Alternatively, it is necessary to expand the shall within a limit which is determined by a tensile strength of the shell material and in which saftey factor is considered. In short, in order that the shell can be safely and surely expanded and contracted, various physical cares should be taken.

The thermal energy storing tank 8 in which a large number of the small spherical thermal energy storing member 37 as discussed above has draining means 41 provided at its bottom. The draining means 41 is so constructed that the small spherical thermal energy storing member 37 is prevented from passing out therethrough, but the heat transfer medium existing in the spaces among the small spherical members 37 is allowed to pass therethrough. To this end, the draining means 41 includes one or more draining openings 44, a draining tube 45, a opening/closing valve 46 for commonly closing the draining tube 45, and a thermal insulation material 47 for covering the draining tube 45 and the opening/closing valve 46. Some types of the draining means are illustrated in the drawings. As shown in Figs. 4 and 5, in one type, the draining opening comprises a single circular hole 44 which is opened in the cylindrical body 27 and which has a smaller diameter than the diameter d of the small spherical thermal energy storing members 37, but one or more cross members 48 horizontally traverse the circular hole so as to prevent the small spherical member 37 from being seated in and closing the circular hole. As shown in Fig. 6, in another type, the draining openings comprise a plurality of circular holes 44 which are opened in the cylindrical body 27 and which have a smaller diameter than the diameter d of the small spherical members 37. In order that each of the small spherical members 37 forming a mass within the tank is prevented from being seated in and closing the smaller circular hole, a pitch P between the adjacent smaller holes is shorter than the diameter d of the small spherical members 37. As shown in Fig. 7, in yet another type, the draining opening comprises a single elongate aperture 44 which is opened in the cylindrical body 27 and a width of which is smaller than the diameter d of the small spherical members 37. As shown in Fig. 8, in yet another type, the draining openings comprise elongate apertures 44 which are opened in the cylindrical body 27 and which have a smaller width than the diamerter d of the small spherical member 37. Furthermore, the draining openings may comprise small rectagular holes (not shown) disposed as like a lattice, which are opened in the cylindrical body 27 and each of which has the smaller sides than the diameter d of the small spherical member 37. The thermal energy storing tank 8 including the draining means as mentioned above is so designed that a ratio of the diameter D to the length L (distance between the end caps 28 and 29) is within the range 1 : 3~6.

When the tank is actually produced, for example, one of the following combinations of the diameter D and the length L may be selected:

D= 950mm and L= 3000mm
D=1250mm and L= 4200mm
D=1600mm and L= 5300mm
D=1800mm and L= 6000mm
D=1900mm and L= 7100mm
D=2100mm and L= 9100mm
D=2500mm and L=10780mm
D=3000mm and L=11200mm
D=3000mm and L=14800mm

The lower a flow velocity of the heat transfer medium passing through the tank is (that is, the longer a resident time within the tank), the higher a thermal efficiency of the heat exchange within the tank is. On the other hand, the lower the flow velocity of the heat transfer medium is, the lower a thermal conductivity is. Therefore, it is necessary to determine an optimum flow velocity of the heat transfer so that both the relationships as mentioned above can be suffici-

ently satisfied. According to many experiments of the present inventors, it has been found that the flow rate of at least 2.5 m^3/h has best to be obtained as a flow velocity of the heat transfer medium. In order to obtain the flow rate of at least 2.5m^3/h, it is necessary to take into account a velocity head of the heat transfer medium deriving from the pump and a pressure loss of the heat transfer medium passing through the tank because the flow rate of the heat transfer medium is governed by these factors. The pressure loss is increased in proportion to the length *L* of the tank and is decreased in inverse proportion to the diameter *D* of the tank. Therefore, if the velocity head of the heat transfer medium is constant, it is possible to determine the flow rate (2.5m^3/h) of the heat transfer medium by suitably selecting a ratio of the diameter *D* to *L*. In short, according to the present invention, the optimum flow rate of the heat transfer can be obtained by selecting a suitable ratio of the diameter *D* to the length *L* from the range 1 : 3~6. The reason why the range 1 : 3~6 is given is that the pressure loss of the heat transfer medium passing through the tank is also affected by a difference of a fluid friction resulting from a difference of a number of the small spherical thermal energy storing members.

Referring to Fig. 9 to 14, operation modes of the thermal energy storing system utilizing latent heat which is constructed as mentioned above will be explained below:

Fig. 9 shows the thermal energy storing mode. This operation mode is commonly carried out during nighttime when the power rate is cheap. When the thermal energy storing mode is commenced, the thermal energy generator or the cold heat generator 1 is driven by a control system (not shown) so that a refrigerant carrier vapor is generated in the vaporizer 3. The refrigerant carrier vapor is compressed in the compressor 4 so that it is changed into a superheated high pressure vapor. The superheated high pressure vapor is then cooled by a cooling water in the condenser 3 so that it is changed into a high pressure liquid. The pressure of this liquid is reduced by the expansion valve 6 so that it is changed a carrier having a low temperature and a low pressure refrigerant. This refrigerant carrier is then vaporized in the vaporizer 3 so that the heat transfer medium having the low solidification point is cooled by the vaporization heat of the refrigerant carrier. On the other hand, the pump 10 is driven and the three-way control valve 22 is so changed that the inlet port *a* is closed, the inlet port *b* is closed and the outlet port *c* is opened. Therefore, the heat transfer medium cooled by the vaporizer 3 is circulated by the pump 10 between vaporizer 3 and the thermal energy storing tank 8, as shown by an arrow 49 in Fig. 9. When the heat transfer medium is passed through the tank 8, it is contacted with the plurality of small spherical thermal energy storing members 37 received therein so that the thermal energy storing medium 38 charged in the small spherical members 37 is solidified at its solidification point. During the solidification of the thermal energy storing medium 38, the cold heat is stored as a latent heat of the solidification in the thermal energy storing medium 38 charaged in the small spherical members 37.

Fig. 10 shows the first thermal energy radiating mode wherein the relationship between *t* and *T* is $t=T$. Commonly, the first thermal energy radiating mode is carried out when the demanded load is large. In this mode, the thermal energy generator side 1 and the pump 10 are stopped. The pump 18 is driven and the three-way control valve 22 is so changed that the inlet port *a* is opened, the inlet port *b* is closed and the outlet port *c* is opened. Therefore, the heat transfer medium is circulated by the pump 18 between the thermal energy storing tank 8 and the chiller 7, as shown by an arrow 50 in Fig. 10. When the heat transfer medium passing through the chiller 7 is fed to the tank 8 so that it is contacted with the small spherical members 37, the heat of the heat transfer medium is transmitted to the small spherical members 37. The thermal energy storing medium charged in the small spherical members 37 is melted at its melting point so that the cold heat which is pre-stored in the thermal energy storing medium is radiated to the heat transfer medium as a latent heat of the melting. Accordingly, the heat transfer medium is cooled to bear the chilling and/or freezing loads.

Fig. 11 shows the second thermal energy radiating mode at the time when the relationship between *t* and *T* is changed from $t=T$ into $t<T$ in the first thermal energy radiating mode of Fig. 10. In this mode, the three-way control valve 22 is so changed that the inlet port *a* is at least partly closed, the inlet port *b* is opened and the outlet port *c* is opened. Therefore, a part of the heat transfer medium discharged from the chiller 7 is passed through the bypass tube 21 as shown by an arrow 51 in Fig. 11. The heat transfer medium passing through the bypass tube 21 is joined at the position of the three-way control valve 22 with the heat transfer medium dischraged from the thermal energy storing tank 8. The joined heat transfer medium is again fed to the chiller 7. In this case, a flow rate of the heat transfer medium passing through the bypass tube 21 is increased in proportion to the difference Δt. In other words, a flow rate of the heat transfer medium passing through the tank 8 is decreased in propotion to the difference Δt. Therefore, a quantity of the energy radiation is reduced so that the temperature of the heat transfer medium at the detecting position 23 is controlled and regulated into the temperature *T*.

Fig. 12 shows the backup operation mode or the third thermal energy radiating mode which is carried out, if necessary. In particular, when the difference Δt comes up to zero in the second thermal energy radiating mode, the three-way control valve 22 is exchanged in the same manner

as in the first thermal energy radiating mode so that the inlet port *a* is opened, the inlet port *b* is closed and the outlet port *c* is opened. As the result, the bypass tube 21 is closed so that the temperature of the heat transfer medium passing through the detecting position 23 is raised. If the relationship between *t* and *T* is changed into $t>T$, the closure of the bypass tube 21 is electrically detected so that the pump 10 and the cold heat generator side 1 are operated. As the result, the heat transfer medium discharged from the chiller 7 is fed not only to the tank 8 but also to the vaporizer 3 by means of the pump 10, as shown by an arrow 52. The heat transfer medium discharged from the vaporizer 3 and the heat transfer medium discharged from the tank 8 are joined at the branching point 15 so that the joined heat transfer medium is fed to the chiller 7.

In short, when the temperature of the heat transfer medium fed to the chiller 7 is hotter than the temperature *T*, the backup cooling is carried out by the vaporizier 3 so that the temperature of the heat transfer medium passing through the detecting position 23 is controlled and regulated into the temperature *T*.

Fig. 13 shows the fourth thermal energy raditating mode at the time when the relationship between *t* and *T* is changed into $t<T$ after the backup operation mode. In this mode, the three-way control valve 22 is so changed that the inlet port *a* is at least partly closed, the inlet port *b* is opened and the outlet port *c* is opened. Therefore, a part of the heat transfer medium discharged from the chiller 7 is passed through the bypass tube 21, as shown by an arrow 53 in Fig. 13. The heat transfer medium passing through the bypass tube 21 is joined at the position of the three-way control valve 22 with the heat transfer medium dischraged from the thermal energy storing tank 8. The joined heat transfer medium is again fed to the chiller 7. Accordingly, the temperature of the heat transfer medium passing through the detecting position 23 is controlled and regulated into the temperature *T* in the same manner as in the second thermal energy radiating mode.

Fig. 14 shows the operation mode at the time when, in the fourth thermal energy radiating mode, as the flow rate of the heat transfer medium passing through the bypass tube 21 is increased, the flow rate of the heat transfer medium fed to the primary side of the pump 10 is decreased so that it becomes less than the output capacity of the pump 10. In this case, a part of the heat transfer medium discharged from the vaporizer 3 is fed to the thermal energy storing tank 8 through the branching point 15 and is then returned back to the vaporizer 3 through the pump 10. In short, it can be said that this operation mode is the thermal energy storing/radiating mode.

In the thermal energy storing and radiating modes as mentioned above, when the heat transfer medium is passed through the thermal energy storing tank 8, some advantages or merits are exhibited. One of the advantages or merits is that the heat transfer medium passing through the tank 8 can be uniformly contacted with the mass of the small spherical thermal energy storing members 37. When the heat trasfer medium is fed to the tank 8, it is introduced from the connection port 30 or 31 into the partitioned chamber 35. Then, the heat transfer medium is passed through the flowing perforations 34 of the diffusing member 32 or 33 so that it is uniformly diffused and spread out within the interior of the tank 8 in the plane which is perpendicular to the flowing direction thereof. Accordingly, the heat transfer medium passing through the tank 8 can be uniformly contacted with the mass of the small spherical thermal energy storing members 37 so that the uniform heat conduction is achieved in each of sections of the mass of the small spherical thermal energy storing members 37. For this reason, in the thermal energy storing system utilizing latent heat according to the present invention, a stable heat conductivity and a reliability can be obtained.

Another of the advantages or merits is that the convections resulting from external rotational forces and the force of gravity are not caused in the heat transfer medium passing the tank 8 because of the horizontal stationary type. The main convection which is caused within the tank 8 is a unidirectional stream which moves from one of the diffusing members 32 and 33 to the other diffusing member so that a generally uniform heat conduction is attained in each of sections of the mass of the small spherical thermal energy storing members 37. In short, the thermal conductivity is uniform in each of said sections. Accordingly, in the thermal energy storing system utilizing latent heat according to the present invention, a stable heat conductivity and a reliability can be obtained. Yet another of advantages or merits is that a ratio of the diameter *D* of the tank to the length *L* thereof is determined within the range 1: 3~6. For this reason, according to the present invention, it is possible to obtain the flow rate of at least $2.5m^3/h$ at which the heat transfer medium is passed through the tank, without causing too much or too little pressure loss, whereby the optimum residence time of the heat transfer medium within the tank can be obtained. Accordingly, optimum thermal conductivity and the optimum thermal efficiency can be achieved.

On the other hand, since the draining opening or openings 44 are formed in the lower portion of the cylindrical body 27 of the tank 8, the drainage of the tank can be easily carried out. Commonly, the tank is provided with manholes 55 and 56 through which the small spherical

members are charged and discharged. If the drainage of the tank is carried out by opening the manhole 56, many of the small spherical members escape from the tank through the opened manhole 56 thereby causing a serious trouble. However, according to the present invention, there are provided the draining opening or openings 44 which are protected from being closed by the small spherical members and which prevent the small spherical members from passing out therethrough. Accordingly, the drainage can be safely carried out.

In the above-mentioned embodiment of the thermal energy storing system utilizing latent heat according to the present invention, there is shown an example in which the present invention is applied to a cooler and/or freezer wherein cold heat is transmitted to the heat exchanger 7 provided at the energy consumption equipment 2. However, it should be understood that an application of the present invention is not limited only to this example. That is, the present invention may be applied to other equipment utilizing cold heat. Furthermore, the invention can be applied to a thermal energy storing system utilizing latent heat wherein a solar equipment or a hot heat source for heating is used in place of the energy generation equipment, wherein the hot heat is transmitted to the heat exchanger provided at the energy consumption equipment, and wherein during the thermal energy storing mode, the hot heat is stored in the thermal energy storing tank and during the thermal energy radiating mode, the hot heat is radiated to feed it to the heat exchanvger provided at the energy consumption equipment. In this application, the exchanging requirements of the three-way control valve 22 are determined as follow:

①During the thermal energy storing operation mode, the three-way control valve is so changed that the inlet port *a* is closed, the inlet port *b* is opened and the outlet port *c* is opened;

②During the first thermal energy raditaing mode wherein the relationship between *t* and *T* is $t=T$ and the backup operation mode wherein the relationship between *t* and *T* is changed into $t<T$, the three-way control valve is so changed that the inlet port *a* is opened, the inlet port *b* is closed and the outlet port *c* is opened; and

③During the thermal energy raditaing mode wherein the relationship between *t* and *T* is changed into $t>T$, the three-way control valve is so changed that the inlet port *a* is opened, the inlet port *b* is opened and the outlet port *c* is opened.

In this way, the thermal energy storing and radiating modes as shown in Fig. 9 to 14 can be carried out in the same manner as in the case where the cold heat is the subject of utilization except that the relationship between *t* and *T* is changed into $t>T$ in the operation modes of Fig. 11 and 13 and that the relationship between *t* and *T* is changed into $t<T$ in the operation mode of Fig. 12.

Of course, in the case where the hot heat is the subject of utilization, when the thermal energy storing medium 38 charged in the small spherical thermal energy storing members 37 is melted at the melting/solidification point, it stores the hot heat, whereas when the thermal energy storing medium 38 is solidified at the melting/solidification point, it radiates the hot heat.

The thermal energy storing medium which is charged in the small spherical thermal energy storing members used in the thermal energy storing system utilizing latent heat according to the present invention will be particularly explained.

As stated hereinbefore, various researches and developments on thermal energy storing mediums have been promoted. In this case, the following matters have been taken into account:

O1 Whether materials for a thermal energy storing medium are easily available and cheap;
O2 Whether an obtained thermal energy storing medium is chemically stable;
O3 Whether a melting point is obtained within a desired range of operation temperatures;
O4 Whether an obtained thermal energy storing medium has a heat of melting per unit volume which is sufficient;
O5 Whether an obtained thermal energy storing medium surely and stably serves although it is subjected to many times of repetition of the melting and the solidification; et cetera.

In this connection, the prior researches and developments realize some results on thermal energy storing mediums. Some of the thermal energy storing mediums obtained from the prior researches and developments can be used in the thermal energy storing system utilizing latent heat according to the present invention. However, as stated hereinbefore, since the prior developments on thermal energy storing plants has been promoted in connection with the solar system and the like, the thermal energy storing mediums which can be put to practical use have a melting/solidification point which is above +5°C. Accordingly, it is impossible to use these thermal energy storing mediums in the thermal energy storing system utilizing latent heat which is applied to a cooler and/or a freezer. Therefore, the thermal energy storing mediums which have a melting/solidification point below 0°C and which are suitable for the thermal energy storing system utilizing latent heat having an operation temperature below 0°C will be explained hereinafter.

One of the thermal energy storing mediums is a liquid which is mainly composed of an aqueous solution including water (H_2O) and small quantities of sulphuric acid (H_2SO_4) added thereto. This thermal energy storing medium has the latent heat of 48.4kwh/m³ (1.74×10^8J/m³) and is suitable for the thermal energy storing system utilizing latent heat having the operation

teperature of about 0°C.

Another of the thermal energy storing mediums is a liquid which is mainly composed of an eutectic mixture of an aqueous salt solution. In particular, the aqueous salt solution has the lowest solidification point at a certain concentration. The aqueous salt solution having such a concentration (eutectic concentration) is used for the thermal energy storing medium. The eutectic mixture or the aqueous solution having the eutectic concentration is solidified as if it is a single substance. Accordingly, the eutectic mixture surely and stably serves as the thermal energy storing medium although it is subjected to many times of repetition of the melting and the solidification. When the eutectic mixture or the thermal energy storing medium is solidified, it stores heat as a latent heat of solidification. Preferred examples of eutectic mixtures are shown below:

1) When the thermal energy storing system is given the operation temperature of −3°C, the eutectic mixture of Na_2CO_3 (sodium carbonate) aqueous solution is used, wherein the eutectic concentration is 37.1%, the eutectic point is −3°C and the latent heat is 48.3kwh/m³ (1.74×10^8J/m³).

2) When the thermal energy storing system is given the operation temperature of −6°C, the eutectic mixture of $KHCO_3$ (potassium bicarbonate) aqueous solution is used, wherein the eutectic concentration is 14.2%, the eutectic point is −6°C and the latent heat is 44.6kwh/m³ (1.61×10^8J/m³.)

3) When the thermal energy storing system is given the operation temperature of −8°C, the eutectic mixture of $BaCl_2$ (barium chloride) aqueous solution is used, wherein the eutectic point is −8°C at this eutectic concentration and the latent heat is 50.5kwh/m³ (1.82×10^8J/m³).

4) When the thermal energy storing system is given the operation temperature of −10°C, the eutectic mixture of KCl (potassium chloride) aqueous solution is used, wherein the eutectic concentration is 19.7%, the eutectic point is −10°C and the latent heat is 49.9kwh/m³ (1.80×10^8J/m³).

5) When the thermal energy storing system is given the operation temperature of −15°C, the eutectic mixture of NH_4Cl (ammonium chloride) aqueous solution is used, wherein the eutectic concentration is 18.9%, the eutectic point is −15°C and the latent heat is 46.4kwh/m³ (1.67×10^8J/m³).

6) When the thermal energy storing system is given the operation temperature of −17°C, the eutectic mixture of NH_4NO_3 (ammonium nitrate) aqueous solution is used, wherein the eutectic concentration is 42.0% and the eutectic point is −17°C.

7) When the thermal energy storing system is given the operation temperature of −18°C, the eutectic mixture of $NaNO_3$ (sodium nitate) aqueous solution is used, wherein the eutectic concentration is 38.5%, the eutectic point is −18°C and the latent heat is 47.5kwh/m³ (1.71×10^8J/m³).

8) When the thermal energy storing system is given the operation temperature of −21°C, the eutectic mixture of NaCl (sodium chloride) aqueous solution is used, wherein the eutectic concentration is 23.0%, the eutectic point is −21°C and the latent heat is 39.4kwh/m³ (1.42×10^8J/m³).

9) When the thermal energy storing system is given the operation temperature of −28°C, the eutectic mixture of NaBr (sodium bromide) aqueous solution is used, wherein the eutectic concentration is 40.1%, the eutectic point is −28°C and the latent heat is 39.3kwh/m³ (1.41×10^8J/m³).

10) When the thermal energy storing system is given the operation temperature of −33°C, the eutectic mixture of $MgCl_2$ (magnesium chloride) aqueous solution is used, wherein the eutectic concentration is 20.6%, the eutectic point is −33°C and the latent heat is 44.6kwh/m³ (1.61×10^8J/m³).

11) When the thermal energy storing system is given the operation temperature of −37°C, the eutectic mixture of K_2CO_3 (potassium carbonate) solution is used, wherein the eutectic concentration is 44.8%, the eutectic point is −37°C and the latent heat is 40.0kwh/m³ (1.44×10^8J/m³)..

Of course, in order to prevent supercooling, if necessary, small quantities of a nucleator may be added to the thermal energy storing medium which is mainly composed of one of the eutectic mixtures as mentioned above. Preferred substances for the nucleator are shown below:

magnesium oxide (MgO)	magnesium hydroxide ($Mg(OH)_2$)
magnesium carbonate ($MgCO_3$)	magnesium sulphate ($MgSO_4$)
magnesium chloride ($MgCl_2$)	magnesium bromide ($MgBr_2$)
calcium oxide (CaO)	calcium hydroxide ($Ca(OH)_2$)
calsium carbonate ($CaCO_3$)	calsium sulphate ($CaSO_4$)
copper sulphate ($CuSO_4$)	nickel sulphate ($NiSO_4$)
zinc sulphate ($ZnSO_4$)	strontium hydroxide ($Sr(OH)_2$)
strontium carbonate ($SrCO_3$)	barium hydroxide ($Ba(OH)_2$)
barium oxide (BaO)	barium carbonate ($BaCO_3$)
sodium sulphate (Na_2SO_4)	sodium tetraborate ($Na_2B_4O_7$)
sodium silicate (Na_2SiO_3)	potassium hydroxide (KOH)
potassium nitrate (KNO_3)	nickel chloride ($NiCl_2$)

The thermal energy storing system which is suitable for a cooler and/or freezer will be more particularly explained hereinafter. In the thermal energy storing system, when there is used a thermal energy storing medium which is mainly composed of an aqueous solution including H_2O and small quantities of H_2SO_4 added thereto, the system is suitable for cooling buildings and regional air-conditioning.

In the thermal energy storing system, when there is used a thermal energy storing medium which is mainly composed of one of the eutectic mixtures of Na_2SO_4 aqueous solution, $KHCO_3$ aqueous solution, $BaCl_2$ aqueous solution and KCl aqueous solution, the system is suitable for a cold heat source which is used in a storage or a reaction process involved in beer production factories, beverage production factories or the like. Also, this system is suitable for a cold heat source which is used in a low temperature reactor involved in a dairy plant. Furthermore, the system is suitable for a cold heat source which is used in a freezer involved in a display case for goods, products or the like. In addition, the system is suitable for a cold heat source which is used in a storage involved in a distribution industry of frozen foods, fruits, flowers or the like.

In the thermal energy storing system, when there is used a thermal energy storing medium which is mainly composed of one of the eutectic mixtures of NH_4Cl aqueous solution, $NaNO_3$ aqueous solution and NH_4NO_3 aqueous solution, the system is suitable for a cold heat source which is used in a meat storage involved in a slaughterhouse, a meat distribution center or the like. Also, this system is suitable for a cold heat source which is used in a rink for ice skating. Furthermore, the system is suitable for a cold heat source which is used in a storage of medicine or blood involved in a medicine industry. In the thermal energy storing system, when there is used a thermal energy storing medium which is mainly composed of one of the eutectic mixtures of NaCl aqueous solution, NaBr aqueous solution, $MgCl_2$ aqueous solution and K_2CO_3 aqueous solution, this system is suitable for a cold heat source which is used in a refrigerated warehouse.

On the other hand, the thermal energy storing system utilizing latent heat according to the present invention can be so constructed that hot heat is the subject of utilization. For this purpose, it is possible to use the thermal energy storing mediums which have been already proposed, for example, $CaCl_2 . 6H_2O$ solution (operation temperature, that is, melting/solidification point=27°C), $MgCl_2 . 6H_2O+Mg(NO_3)_2 . 6H_2O$ (operation temperature=57°C), $Mg(NO_3)_2 . 6H_2O$ (operation temperature=87°C) or the like. However, when the thermal energy storing system is used as a hot heat source for a heating of buildings, a hot-water supply, a hot-well, a region air-conditioning or the like, it is impossible to suitably use the thermal energy storing medium which is mainly composed of NaOH (sodium hydroxide) aqueous solution.

This thermal energy storing medium, to which one of the abovementioned nucleators may be added, has the eutectic concentration of 60%, the operation temperature of 64°C and the latent heat of 60kwh/m³ ($2.45\times10^8 J/m^3$).

As discussed hereinbefore, according to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein a real temperature of the heat transfer medium is detected as a control signal when it enters into the heat exchanger provided at the energy consumption side and then a flow rate of the heat transfer medium passed through the thermal energy storing tank is regulated in response to the control signal, whereby a temperature of the heat transfer medium supplied to the heat exchanger of the energy consumption side is, at all times, in accordance with predetermined energy consumption requirements of the energy consumption side.

Also, according to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein the thermal energy storing tank having a given volume can be given a maximum thermal energy storage capacity, wherein thermal conductivity per unit volume is so good as to be capable of shortening the thermal energy storage/radiation time as much as possible, wherein portions of the tank which may be subjected to corrosion are few so that a durability thereof can be increased, and wherein the design of the tank need not be

limited by thermal energy storing members. Furthermore, according to the present invention, it is possible to attain the thermal energy storing system utilzing latent heat wherein there is provided means for uniformly diffusing and spreading out the heat transfer medium within the thermal energy storing tank in a plane perpendicular to a direction along which it enters into the tank, especially just after the entrance, so that the heat transfer medium is uniformly contacted with the small spherical thermal energy storing members. Furthermore, according to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein the thermal energy storing tank per se is of a horizontal stationary type so as to eliminate effects resulting from external forces and the force of gravity, by which unforeseen convections are caused in the heat transfer medium, whereby a uniform convection is caused in each of sections of the mass of small spherical thermal energy storing members so that a uniform heat conduction can be obtained in each of said sections. Furthermore, according to the present invention, it is possible to attain the thermal energy storing system utilzing latent heat wherein there is provided the thermal energy storing tank which assures a velocity of a heat transfer medium (residence time thereof within the tank) for obtaining a good thermal efficiency of heat exchange by determining a ratio of a diameter of the tank to a length thereof within the range 1 : 3~6, which governs a pressure loss of the heat transfer medium passing through the tank.

In addition, according to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein there is provided the thermal energy storing tank which is designed so that a drainage of the tank in which the small spherical thermal energy storing members are densely received and settled can be easily carried out, if necessary, without falling the small spherical members downwardly, and that is convenient to handle in situ.

On the other hand, according to the present invention, it is also to attain the thermal energy storing system utilizing latent heat wherein a thermal energy storing medium having a melting/-solidification point of −3, −6, −8 or −10°C is charged in the small spherical thermal energy storing members. This system is suitable for a cold heat source which is used in a storage and/or a reaction process involved in beer production factories, beverage production factories or the like. Also, the system is suitable for a cold heat source which is used in a low temperature reactor included in a dairy plant. Furthermore, the system is suitable for a cold heat source which is used in a freezer involved in a display case for goods, products or the like. In addition, the system is suitable for a cold heat source which is used in a storage involved in a distribution industry of frozen foods, fruits, flowers or the like.

Also, according to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein a thermal energy storing medium having a melting/solidification point of −15, −17, −18 or −21°C is charged in the small spherical thermal energy storing members, and wherein the charged small spherical members are received in the thermal energy storing tank. This system is suitable for a cold heat source which is used in a meat storage involved in a slaughterhouse, a meat distribution center or the like. Also, the system is suitable for a cold heat source which is used in a rink for ice skating. Furthermore, the system is suitable for a cold heat source which is used in a storage of medicine or blood involved in a medicine industry. According to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein a thermal energy storing medium having a melting/solidiffication point of 0°C is charged in the small spherical thermal energy storing members, and wherein the charged small spherical members are received in the thermal energy storing tank. This system is suitable for a cold heat source which is used in a cooler of buildings.

Furthermore, according to the present invention, it is possible to attain the thermal energy storing system utilizing latent heat wherein a thermal energy storing medium having a melting/-solidification point of −28, −33 or −37°C is charged in the small spherical thermal energy storing members, and wherein the charged small spherical members are received in the thermal energy storing tank. This system is sutable for a cold heat source which is used in a freezing warehouse.

Finally, according to the present invention, it is also possible to attain the thermal energy storing system utilizing latent heat wherein there is used a thermal energy storing medium having a melting/solidification point of 64°C. This system is suitable for a heating of buildings, a hot-water supply, a hot-well or the like.

CLAIMS

1. A thermal energy storage and discharge system utilizing latent heat and comprising a conduit array arranged to pass heat transfer medium between a first heat exchanger arranged to receive thermal energy into said system and a thermal energy storage tank arranged to store thermal energy received into said system and between said tank and a second heat exchanger arranged to discharge thermal energy from said system,

said tank being charged with spheroidal thermal energy storing members each charged with a thermal energy storing medium, said conduit array comprising a first conduit element arranged to pass heat transfer medium under the action of pump means from said first heat exchanger to

said tank and to return heat transfer medium from said tank to said first heat exchanger, a second conduit element arranged to pass heat transfer medium under the action of pump means from said second heat exchanger to said tank and to return heat transfer medium from said tank to said second heat exchanger, and a bypass conduit element branching out from said second conduit element at a first junction upstream of said second heat exchanger and rejoining said second conduit element at a second junction downstream of said second heat exchanger, said system further comprising a temperature sensing means arranged to monitor the temperature of said heat transfer medium passing from said first junction to said second heat exchanger and to generate a signal, control valve means arranged to adjust the flow rate of said heat transfer medium through said second conduit element and said bypass conduit element and control means arranged to operate said control valve means in response to said signal to increase or decrease the flow rate of said heat transfer medium through said bypass conduit element and said tank when the temperaure of said medium monitored by said sensing means deviates from a preset value whereby to reduce the deviation from said preset value.

2. A system as claimed in claim 1 wherein said control valve means comprises a three-way control valve at said first junction.

3. A system as claimed in either of claims 1 and 2 wherein said second conduit element joins said first conduit element upstream of and downstream of said first heat exchanger.

4. A system as claimed in any one of claims 1 to 3 wherein said pump means serving to pass heat transfer medium through said first heat exchanger is arranged to pump said heat transfer medium through said tank in the opposite direction to that in which said pump means serving to pass heat transfer medium through said second heat exchange is arranged to pass said heat transfer medium through said tank.

5. A system as claimed in any one of claims 1 to 4 wherein said tank comprises a hollow closed ended cylindrical body member having a substantially horizontal cylindrical axis, having inlet and outlet ports for heat transfer medium passing through said conduit array at the opposite ends of said body member, and having flow diffusing members within said body member in facing relation with said ports.

6. A system as claimed in claim 5 wherein said diffusing members comprise circular multiply perforated plate members.

7. A system as claimed in either of claims 5 and 6 wherein the ratio of the diameter to the length of said cylindrical body member is from 1:3 to 1:6.

8. A system as claimed in any one of claims 5 to 7 wherein said cylindrical body member is provided on its underside with at least one drainage port whereby to permit the drainage from said body member of heat transfer medium contained therein, the opening to said drainage port being so dimensioned as to prevent said spheroidal thermal energy storing members from being drawn out therethrough.

9. A system as claimed in claim 8 wherein the aperture of said drainage port opening into said cylindrical body member is circular in cross section and of a diameter smaller than that of said spheroidal members, said aperture having provided thereover at least one horizontal cross member to prevent any said spheroidal member from seating in and sealing said aperture.

10. A system as claimed in claim 8 wherein said drainage port has a plurality of apertures at its opening into said cylindrical body member, said apertures being circular of a diameter less than that of said spheroidal members, the centres of adjacent apertures being spaced apart by a distance less than the diameter of said spheroidal members whereby a said spheroidal member seated in one said aperture prevents further said spheroidal members from seating in adjacent apertures.

11. A system as claimed in claim 8 wherein the aperture of said drainage port opening into said cylindrical body member is elongate, the width thereof being less than the diameter of said spheroidal members.

12. A system as claimed in claim 8 wherein the aperture of said drainage port opening into said cylindrical body member comprises a lattice like array of rectangular apertures the shorter dimension of each being less than the diameter of said spheroidal members.

13. A system as claimed in any one of claims 1 to 12 wherein said first heat exchanger comprises apparatus serving in the operation of said first heat exchanger to reduce the temperature of heat transfer medium passing through said first conduit element and said second heat exchanger comprises apparatus serving in the operation of said second heat exchanger to increase the temperature of heat transfer medium passing through said second conduit element.

14. A system as claimed in claim 13 wherein said control means is arranged to increase flow of heat transfer medium through said bypass conduit element when the signal from said temperature sensing means indicates the monitored temperature to be below said preset value and to increase flow of heat transfer medium through said tank when the signal from said temperature sensing means indicates the monitored temperature to be above said preset value.

15. A system as claimed in any one of claims 1 to 12 wherein said first heat exchanger comprises apparatus serving in the operation of said first heat exchanger to increase the

temperature of heat transfer medium passing through said first conduit element and said second heat exchanger comprises apparatus serving in the operation of said second heat exchanger to decrease the temperature of heat transfer medium passing through said second conduit element.

16. A system as claimed in claim 15 wherein said control means is arranged to increase flow of heat transfer medium through said bypass conduit element when the signal from said temperature sensing means indicates the monitored temperature to be above said preset value and to increase flow of heat transfer medium through said tank when the signal from said temperature sensing means indicates the monitored temperature to be below said preset value.

17. A system as claimed in any one of claims 1 to 16 wherein said thermal energy storing medium with which said spheroidal members are charged comprises an aqueous eutectic solution containing at least one of the following:
Na_2CO_3, $KHCO_3$, $BaCl_2$, KCl, NH_4Cl, NH_4NO_3, $CaCl_2$, NaBr, $MgCl_2$, K_2CO_3, NaOH and H_2SO_4.

18. A system as claimed in claim 17 wherein said aqueous eutectic solution contains as a nucleator at least one of the following:
MgO, $Mg(OH)_2$, $MgCO_3$, $MgSO_4$, $MgCl_2$, $MgBr_2$, CaO, $Ca(OH)_2$, $CaCO_3$, $CaSO_4$, $CuSO_4$, $NiSO_4$, $ZnSO_4$, $Sr(OH)_2$, $SrCO_3$, $Ba(OH)_2$, BaO, $BaCO_3$, Na_2SO_4, $Na_2B_4O_7$, Na_2SiO_3, KOH, KNO_3 and $NiCl_2$.

19. A thermal energy storage system utilizing latent heat comprising a heat transmitting tube for a time of thermal energy storing mode and a heat transmitting tube for a time of thermal energy radiating mode, said heat transmitting tube for the thermal energy storing mode being arranged to pass a heat transfer medium, which is discharged from a heat exchanger provided at an energy generation side, to a thermal energy storing tank under the action of a pump and return said heat transfer medium to the heat exchanger provided at said energy generation side, said thermal energy storing tank densely receiving small spherical thermal energy storing members therewithin, each of said small spherical thermal energy storing members being charged with a thermal energy storing medium, said heat transmitting tube for the thermal energy radiating mode being branched out from a part of the first-mentioned heat transmitting tube at the upstream side of said thermal energy storing tank and connected, through a heat exchanger provided at an energy consumption side, to a part of the first-mentioned heat transmitting tube at the downstream side of said thermal enegy storing tank, thereby passing a heat transfer medium, which has been discharged from the heat exchanger provided at said energy consumption side, to the thermal energy storing tank under the action of a pump and then passng said heat transfer medium to the heat exchanger provided at said energy consumption side, wherein said thermal energy storing system utilizing latent heat further comprises a bypass tube for connecting the parts of the heat transmitting tube for the thermal energy radiating mode at the upstream and downstream sides of the heat exchanger provided at said energy consumption side and a three-way control valve arranged at the junction point between the heat transmitting tube for the thermal energy storing mode and bypass tube which are so constructed that when the temperature t of the heat transfer medium detected at a position short of the point where the heat transfer medium enters through said junction point into the heat exchanger provided at said energy consumption side becomes higher than a predetermined temperature T at the same position, the difference Δt between the temperatures is used as a control signal to actuate said three-way control valve to cause a part of the heat transfer medium, which is discharged from the heat exchanger provided at said energy consumption side, to pass through the bypass tube and return into the heat exchanger provided at said energy consumption side, thereby adjusting the flow rate of the heat transfer medium which is passed through said thermal energy storing tank.

20. A thermal energy storage system utilizing latent heat comprising a heat transmitting tube for a time of thermal energy storing mode and a heat transmitting tube for a time of thermal energy radiating mode, said heat transmitting tube for the thermal energy storing mode being arranged to pass a heat transfer medium, which is discharged from a heat exchanger provided at an energy generation side, to a thermal energy storing tank under the action of a pump and return said heat transfer medium to the heat exchanger provided at said energy generation side, said thermal energy storing tank densely receiving small spherical thermal energy storing members therewithin, each of said small spherical thermal energy storing members being charged with a thermal energy storing medium, said heat transmitting tube for the thermal energy radiating mode being branched out from a part of the first-mentioned heat transmitting tube at the upstream side of said thermal energy storing tank and connected, through a heat exchanger provided at an energy consumption side, to a part of the first-mentioned heat transmitting tube at the downstream side of said thermal energy storing tank, thereby passing a heat transfer medium, which has been discharged from the heat exchanger provided at said energy consumption side, to the thermal energy storing tank under the action of a pump and then passing said heat transfer medium to the heat exchanger provided at said energy consumption side, wherein said thermal energy storing system utilizing latent heat further comprises a bypass tube for connecting the parts of the heat transmitting tube for the thermal energy radiating mode at the upstream and downstream sides of the heat exchanger provided at said energy consumption

side and a three-way control valve arranged at the junction point between the heat transmitting tube for the thermal energy storing mode and the bypass tube which are so constructed that when the temperaure t of the heat transfer medium detected at a position short of the point where the heat transfer medium enters through said junction point into the heat exchanger provided at said energy consumption side becomes higher than a predetermined temperature T at the same position, the difference Δt between the temperatures is used as a control signal to actuate said three-way control valve to cause a part of the heat transfer medium, which is discharged from the heat exchanger provided at said energy consumption side, to pass through the bypass tube and return into the heat exchanger provided at said energy consumption side, thereby adjusting the flow rate of the heat transfer medium which is passed through said thermal energy storing tank, wherein the thermal energy storing tank is of a horizontal stationary type, which comprises a cylindrical body, end caps fixed to the opposite ends of said cylindrical body, connection ports, flow diffusing members disposed near the opposite ends of the cylindrical body in confronting relation to said connection ports, and a draining means formed at the lower position of the horizontal body, wherein the ratio of the diameter D to the horizontal length L of the tank is within the range 1:3–6 and wherein the tank contains a plurality of small spherical thermal energy storing members, each filled with a thermal energy storing medium, which are closely received in an inside chamber of the tank defined by said flow diffusing members, said draining means being formed of a draining tube, one or more draining openings and a valve for closing said draining tube, said one or more draining openings being so formed as to inhibit the passage of said small spherical thermal energy storing members but to allow the passage of the heat transfer medium.

21. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the energy generation side includes means for generating a cold heat and the energy consumption side comprises equipment for utilizing the cold heat;

wherein when the relationship between t and T is $t=T$, the three-way control valve is operated by a control system so that a first thermal energy radiating mode is obtained, whereby all of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the thermal energy storing tank by the pump and is then returned back to the heat exchanger provided at the energy consumption side;

wherein when the relationship between t and T is $t<T$, the three-way control valve is operated by the control system so that a second thermal energy radiating mode is obtained, whereby a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the bypass tube and is then returned back to the heat exchanger provided at the energy consumption side, while the flow rate of the heat transfer medium which is passed through the thermal energy storing tank is controlled and regulated in proportion to the difference Δt;

wherein when the relationship between t and T is $t>T$, the three-way control valve is operated by said control system to prevent flow of heat transfer medium through the bypass tube and the pump and the heat exchanger provided at the energy generation side are, if necessary, actuated by the control system whereby, a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the heat exchanger provided at the energy generation side and is then returned back to the heat exchanger provided at the energy consumption side so that a backup operation mode or a third thermal energy radiating mode is obtained;

wherein when the relationship between t and T becomes $t<T$ during the backup operation mode, the three-way control valve is operated so that a fourth thermal energy radiating mode is obtained, whereby a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the bypass tube and is then returned back to the heat exchanger provided at the energy consumption side, while a flow rate of the heat transfer medium which is passed through the thermal energy storing tank is controlled and regulated in proportion to the difference Δt; and

wherein when a flow rate of the heat transfer medium fed to the primary side of the pump becomes less than the output capacity thereof during the fourth thermal energy radiating mode for the reason that as a flow rate of the heat transfer medium which is passed through the bypass tube is increased, the flow rate of the heat transfer medium which is fed to the primary side of said pump is decreased, a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy generation side is directed to the primary side of said pump through the thermal energy storing tank and is then returned back to the heat exchanger provided at the energy generation side so that both a thermal energy storing mode and a thermal energy radiating mode are obtained.

22. A thermal energy storing system utilizing latent heat set forth in Claim 19:

wherein the energy generation side includes means for generating a hot heat and the energy consumption side comprises equipment for utilizing the hot heat;

wherein when the relationship between t and T is $t=T$, the three-way control valve is

operated by a control system so that a first thermal energy radiating mode is obtained, whereby all of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the thermal energy storing tank by the pump and is then returned back to the heat exchanger provided at the energy consumption side;

wherein when the relationship between t and T is $t>T$, the three-way control valve is operated by the control system so that a second thermal energy radiating mode is obtained, whereby a part of the heat transfer medium which is dsicharged from the heat exchanger provided at the energy consumption side is passed through the bypass tube and is then returned back to the heat exchanger provided at the energy consumption side, while the flow rate of the heat transfer medium which is passed through the thermal energy storing tank is controlled and regulated in proportion to the difference Δt;

wherein when the relationship between t and T is $t<T$, the three-way control valve is operated by said control system to prevent flow of heat transfer medium through the bypass tube and the pump and the heat exchanger provided at the energy generation side are, if necessary, actuated by the control system whereby a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the heat exchanger provided at the energy generation side and is then returned back to the heat exchanger provided at the energy consumption side so that a backup operation mode or a third thermal energy radiating mode is obtained;

wherein when the relationship between t and T becomes $t>T$ during the backup operation mode, the three-way control valve is operated so that a forth thermal energy radiating mode is obtained, whereby a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy consumption side is passed through the bypass tube and is then returned back to the heat exchanger provided at the energy consumption side, while a flow rate of the heat transfer medium which is passed through the thermal energy storing tank is controlled and regulated in proportion to the difference Δt; and

wherein when a flow rate of the heat transfer medium fed to the primary side of the pump becomes less than the output capacity thereof during the fourth thermal energy radiating mode for the reason that as a flow rate of the heat transfer medium which is passed through the bypass tube is increased, the flow rate of the heat transfer medium which is fed to the primary side of said pump is decreased, a part of the heat transfer medium which is discharged from the heat exchanger provided at the energy generation side is directed to the primary side of said pump through the thermal energy storing tank and is then returned back to the heat exchanger provided at the energy generation side so that both a thermal energy storing mode and a thermal energy radiating mode are obtained.

23. A thermal energy storing system utilizing latent heat as set forth in Claim 20, wherein the draining opening of the draining means comprises a single circular hole which is opened in the cylindrical body of the thermal energy storing tank and which has a smaller diameter than the diameter d of the small spherical thermal energy storing members, but one or more cross members horizontally traverse the circular hole so as to prevent the small spherical members from being seated in and closing the circular hole.

24. A thermal energy storing system utilizing latent heat as set forth in Claim 20, wherein the draining openings of the draining means comprise a plurality of circular holes which are opened in the cylindrical body of the thermal energy storing tank and which have a shorter diameter than the diameter d of the small spherical thermal energy storing members, and wherein a pitch P between the adjacent circular holes is shorter than the diameter d of the small spherical members so that each of the small spherical members forming a mass within the tank is prevented from being seated in and closing the smaller circular hole.

25. A thermal energy storing system utilizing latent heat as set forth in Claim 20, wherein the draining opening of the draining means comprises one or more elongate apertures which are opened in the cylindrical body of the thermal energy storing tank and which have a narrower width than the diameter d of the small spherical thermal energy storing members.

26. A thermal energy storing system utilizing latent heat as set forth in Claim 20, wherein the draining openings of the draining means comprise small rectangular holes disposed as like a lattice, which are opened in the cylindrical body of the thermal energy storing tank and each of which has shorter sides than the diameter d of the small spherical thermal energy storing members.

27. A thermal energy storing system utilizing latent heat as set forth in Claim 20, wherein the flow diffusing members which are disposed near the opposite ends of the cylindrical body of the thermal energy storing tank in confronting relation to the connection ports comprise circular plate members in each of which a plurality of flowing perforations is formed.

28. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing meduim which is mainly composed of an eutectic mixture of sodium carbonate (Na_2CO_3) aqueous solution.

29. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of potassium bicarbonate ($KHCO_3$) aqueous solution.

30. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of barium chloride ($BaCl_2$) aqueous solution.

31. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of potassium chloride (KCl) aqueous solution.

32. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of ammonium chloride (NH_4Cl) aqueous solution.

33. A thermal energy storing system utilizing latent hat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of ammonium nitrate (NH_4NO_3) aqueous solution.

34. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of sodium nitrate ($NaNO_3$) aqueous solution.

35. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of calcium chloride ($CaCl_2$) aqueous solution.

36. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of sodium bromide (NaBr) aqueous solution.

37. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of magnesium chloride ($MgCl_2$) aqueous solution.

38. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of potassium carbonate (K_2CO_3) aqueous solution.

39. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of an eutectic mixture of sodium hydroxide (NaOH) aqueous solution.

40. A thermal energy storing system utilizing latent heat as set forth in Claim 19, wherein the small spherical thermal energy storing members which are densely received in the thermal energy storing tank are charged with a thermal energy storing medium which is mainly composed of a solution including water (H_2O) and small quantities of sulphuric acid (H_2SO_4) added thereto.

41. A thermal enregy storing system utilizing latent heat as set forth in any one of Claims 28 through 40, wherein the solution with which the small spherical thermal energy storing members are charged includes as a nucleator small quantities of at least one material selected from the group consisting of magnesium oxide (MgO), magnesium hydroxide ($Mg(OH)_2$), magnesium carbonate ($MgCO_3$), magnesium sulphate ($MgSO_4$), magnesium chloride ($MgCl_2$), magnesium bromide ($MgBr_2$), calcium oxide (CaO), calcium hydroxide ($Ca(OH)_2$), calsium carbonate ($CaCO_3$), calcium sulphate ($CaSO_4$), copper sulphate ($CuSO_4$), nickel sulphate ($NiSO_4$), zinc sulphate ($ZnSO_4$) strontium hydroxide ($Sr(OH)_2$), strontium carbonate ($SrCO_3$), barium hydroxide ($Ba(OH)_2$), barium oxide (BaO), barium carbonate ($BaCO_3$), sodium sulphate (Na_2SO_4), sodium tetraborate ($Na_2B_4O_7$), sodium silicate (Na_2SiO_3), potassium hydroxide (KOH), potassium nitrate (KNO_3) and nickel chloride ($NiCl_2$).

Printed in the United Kingdom for Her Majesty's Stationery Office, Dd 8818935, 1986, 4235.
Published at The Patent Office, 25 Southampton Buildings, London, WC2A 1AY, from which copies may be obtained.